Week 6

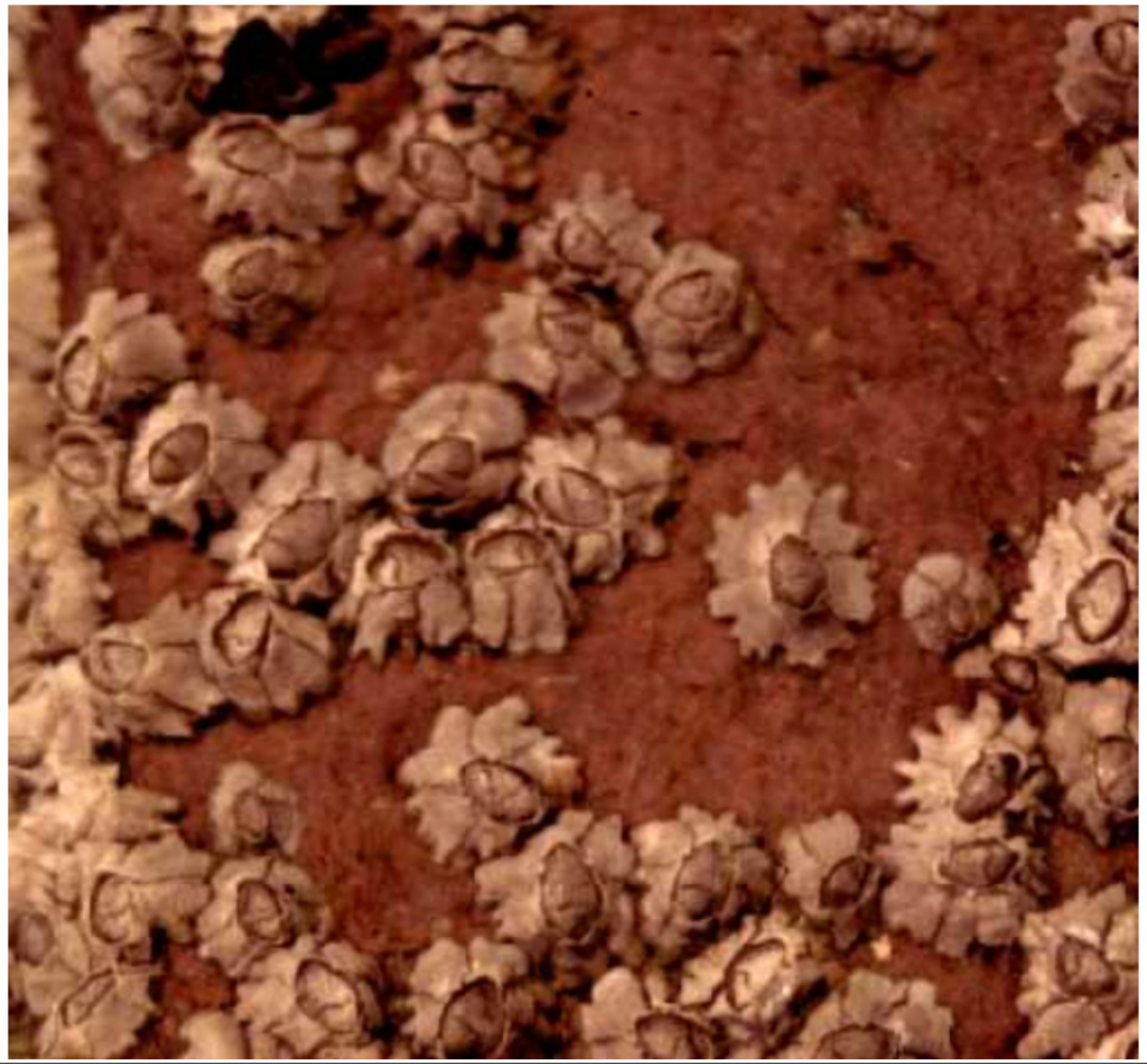
(Preparing for) **Tuesday's lecture:**

Budgeting homework time (50 min): Read the second half of section 16.1 titled "Variation caused by the environment". This is just 1337 words with 3 figures. Just reading the text will take 8 minutes. Yet the figures contain data, thus, when done properly, when you pause to decipher each figure, try Integrating Questions, and take notes, this assignment will take you more like 50 minutes.

1. _______ **For Tuesday's lecture,** read the second half of section 16.1 titled "Variation caused by the environment".
2. _______ **Try to answer some Integrating Questions and Review Questions.** As you read the ICB textbook always attempt to test yourself a little, answer at least one of each set.
3. _______ (Trifecta): **Prepare to explain (aloud) Figures 16.6, 16.7, and 16.8 in class**. (Purpose, Methods, Findings).
4. _______ **Advanced**: Use the papers in the Bibliography to learn more, particularly if you don't quite understand something in the figures. Find out where the figure came from and go see how the author explains the results. Maybe their explanation will make more sense to you.

Chapter 16: Variation and Population Genetics

Look around your classroom – how many people in the room look just like you? What is the makeup of the class in terms of hair, eye or skin color? What about height? You will find that there is some variation in all of these traits. Much of that variation has a genetic component and all of the variation relates to information. In this chapter you will consider information at the level of the individual, first by investigating the causes of variation among individuals, then by examining how genetic information within individuals plays out at the population leve genetic and environment variation within species.



you are here		Big Ideas of biology				
		Information	Evolution	Cells	Homeostasis	Emergent Properties
levels of the biological hierarchy	molecules	1	4	7	10	13
	cells	2	5	8	11	14
	organisms I	3	6	9	12	15
	organisms II	16	19	22	28	25
	populations	17	20	23	29	26
	ecological systems	18	21	24	30	27

The barnacle Chthamalu attaches to a hard substr of these are, and one shaped as if the volcano were bent over. Information in the environment triggers the growth of different morphs in individuals. Courtesy of Curt Lively, Bloomington, IN.

Section 16.1: What causes individual variation?

Biology Learning Objectives

- Evaluate the processes/mechanisms by which variation is generated in organisms and how this affects information at the population level and natural selection.

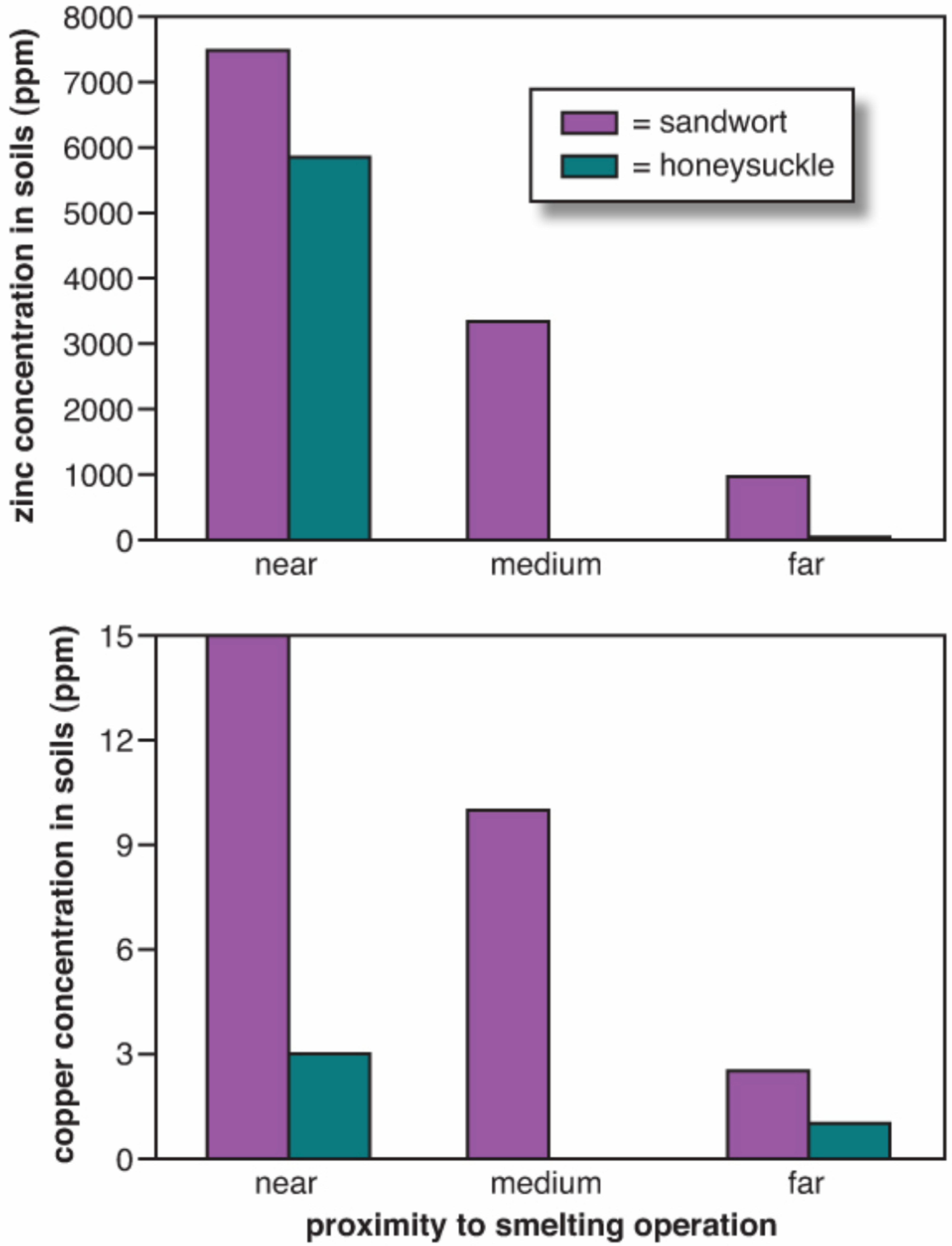


Figure 16.6 Contamination in soils surrounding a smelting operation in Pennsylvania. Sandwort plants were collected at three sites (near, medium, far) and honeysuckle plants were collected at two sites (near and far). **A,** Zinc concentrations in parts per million (ppm). **B,** Copper concentrations in parts

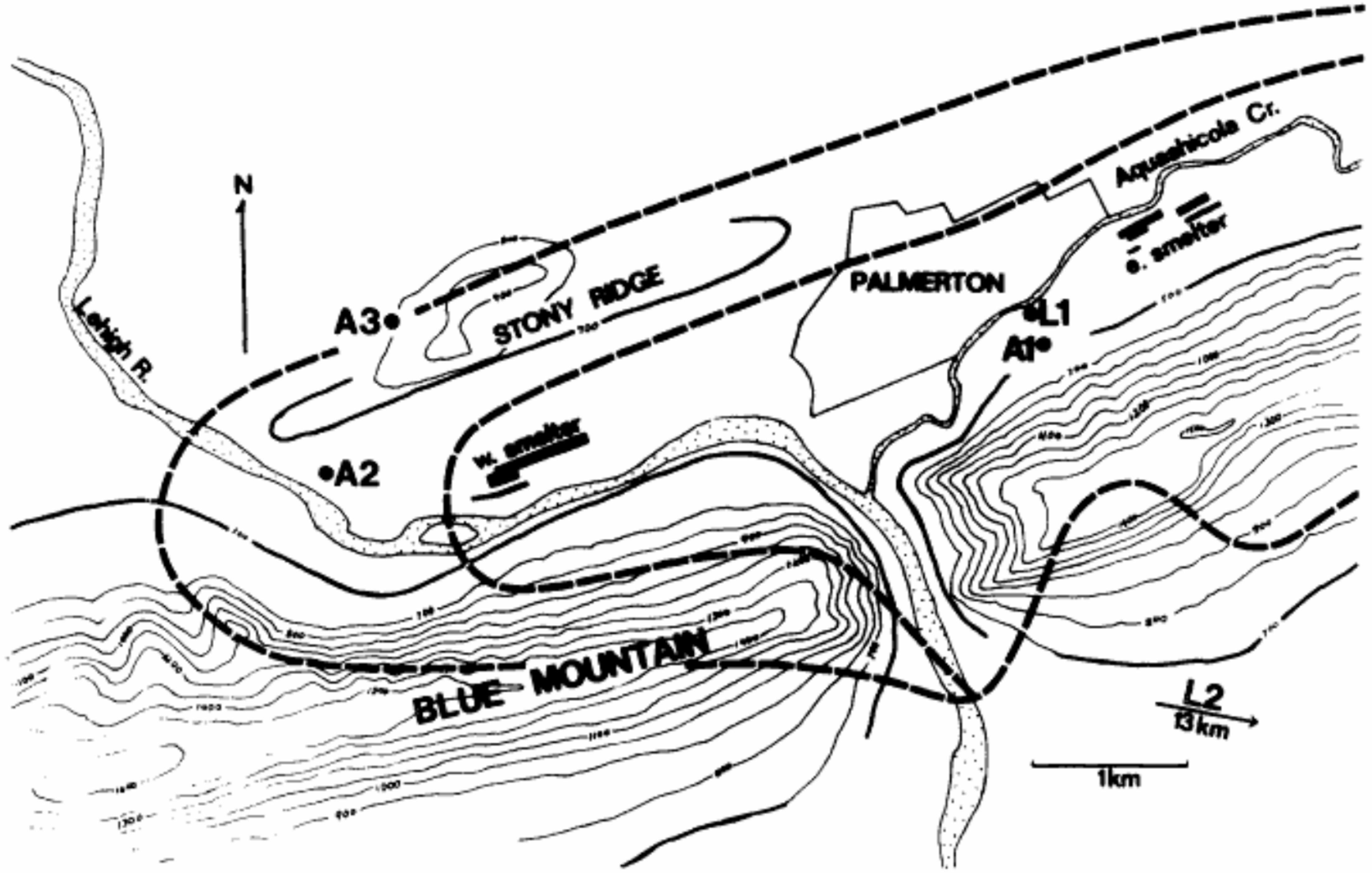


Fig. 1. The Lehigh Water Gap and vicinity. Included are Palmerton, the smelters, contour lines (el. in ft), and the *Arenaria* (A) and *Lonicera* (L) sample sites. The heavy dashed lines show the areas of high (center area including A1 and L1), intermediate (second ring including A2), and low (outside of dashed lines) sulfation values for 1970 (Nash, 1971). According to Nash (1975), the high area had sulfation rates exceeding 9.0 μg $SO_3/cm^2 \cdot day$ for at least 2 mo, while in the low area "clean" air values were consistently recorded.

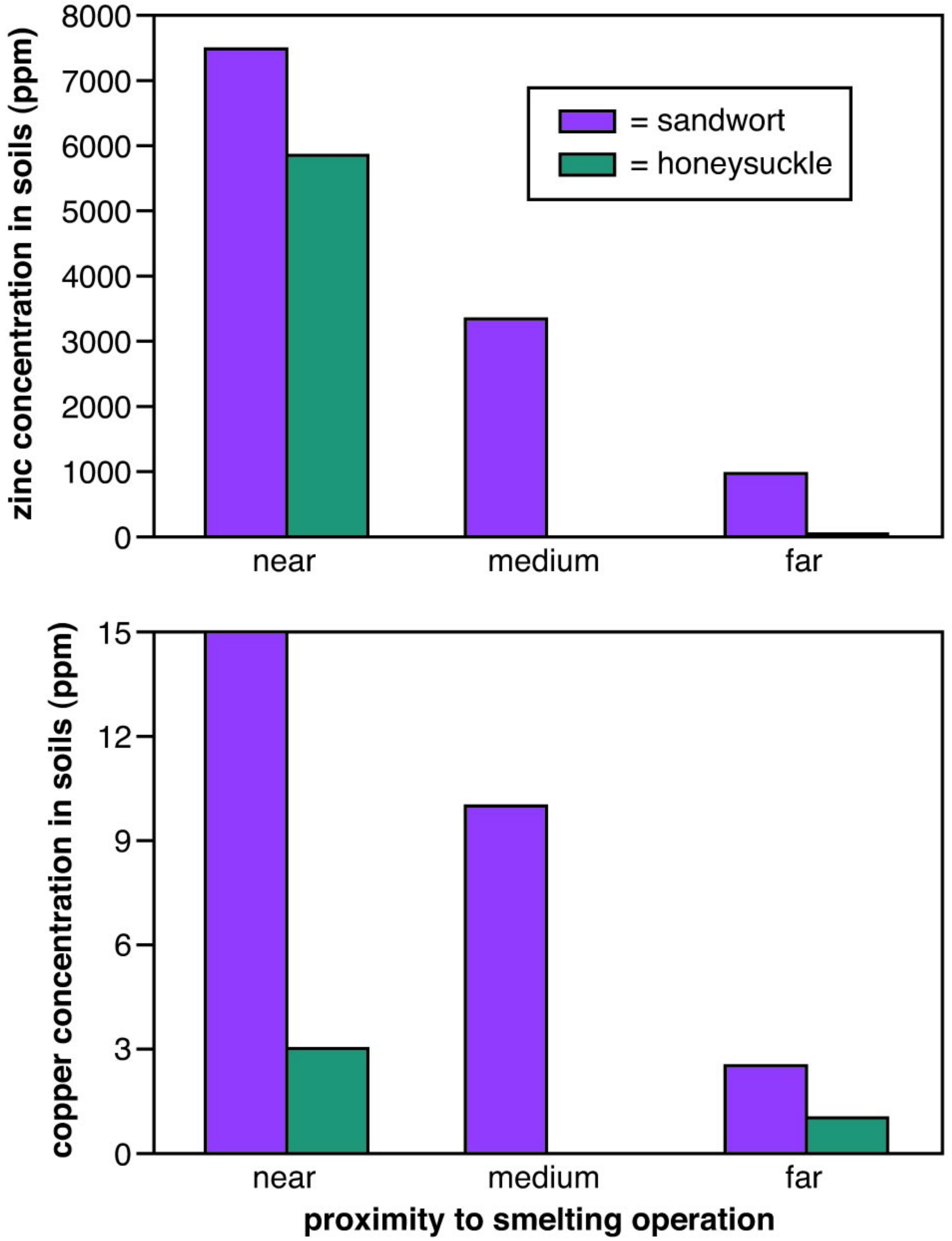


Figure 16.6

Data from Caiazza & Quinn, 1980, Table 1.

BULLETIN OF THE TORREY BOTANICAL CLUB

VOL. 107, No. 1, pp. 9–18 JANUARY–MARCH 1980

Leaf morphology in *Arenaria patula* and *Lonicera japonica* along a pollution gradient

Nicholas A. Caiazza, Jr. and James A. Quinn [1]

Department of Botany, P.O. Box 1059, Rutgers University, Piscataway, New Jersey 08854

CAIAZZA, NICHOLAS A., JR., and JAMES A. QUINN. (Dept. Bot., Rutgers Univ., Piscataway, N.J. 08854). Leaf morphology in *Arenaria patula* and *Lonicera japonica* along a pollution gradient. Bull. Torrey Bot. Club 107: 9–18. 1980.—Certain plant species have persisted in denuded areas subjected to heavy metals (Zn, Cd, Pb, Cu) and SO_2 air pollution from two zinc smelters in Palmerton, Pennsylvania. The objectives of this research were to determine if correlations existed between the degree of environmental pollution and changes in leaf morphology along a local pollution gradient, and to determine the relative importance of genetic and environmental components responsible for the observed variations in leaf phenotypes. Leaves and epidermal peels from field samples of *Arenaria patula* and *Lonicera japonica* were examined microscopically. Sample sites were chosen to coincide with a previously documented air pollution gradient, and field conditions were monitored. Although stomatal size and leaf volume were not significantly different among populations of a species in the field, those populations of *Arenaria* and *Lonicera* exposed to the highest concentrations of pollutants exhibited the lowest stomatal density and the highest trichome density. Such alterations in leaf morphology should reduce the penetration of gaseous, and especially particulate matter, into the mesophyll and thus reduce susceptibility to pollution damage. Comparisons of results from the field with those of common environments (greenhouse and greenhouse courtyard) indicated phenotypic plasticity as the source of most of the observed field differences in *Arenaria* and *Lonicera;* however, they also provided some evidence for genetic dissimilarity in *Lonicera* populations in stomatal and trichome densities.

Key words: *Arenaria patula;* leaf morphology; *Lonicera japonica;* phenotypic plastic-

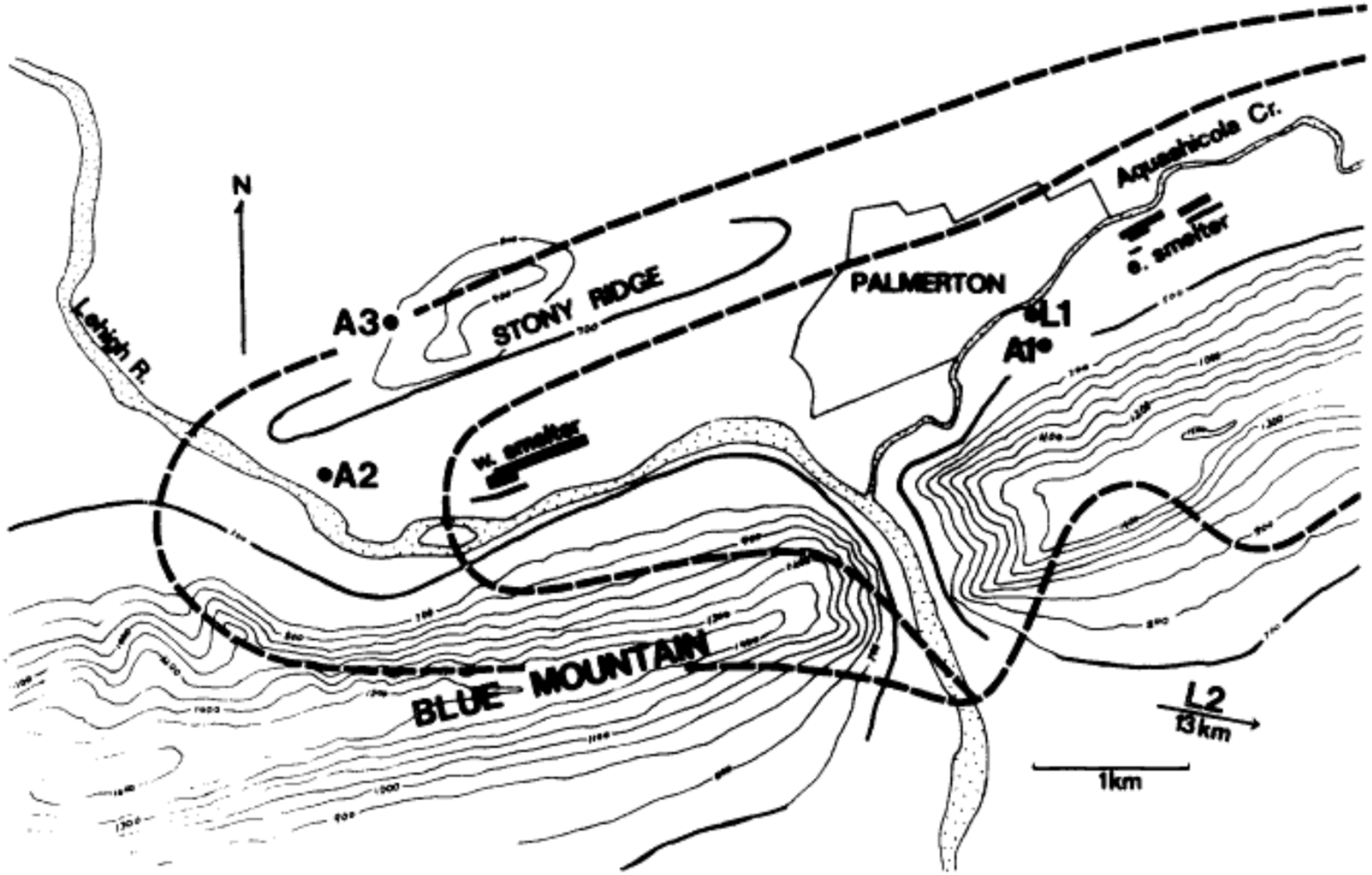


Fig. 1. The Lehigh Water Gap and vicinity. Included are Palmerton, the smelters, contour lines (el. in ft), and the *Arenaria* (A) and *Lonicera* (L) sample sites. The heavy dashed lines show the areas of high (center area including A1 and L1), intermediate (second ring including A2), and low (outside of dashed lines) sulfation values for 1970 (Nash, 1971). According to Nash (1975), the high area had sulfation rates exceeding 9.0 μg $SO_3/cm^2 \cdot day$ for at least 2 mo, while in the low area "clean" air values were consistently recorded.

Table 1. Comparative data for five of the environmental factors monitored at the five study sites.

Sample site	Zinc (ppm)	Copper (ppm)	pH (1:1)	Mean soil moisture[1] (%)	Relative evaporation April 14–16 (ml)	Relative evaporation June 22–24 (ml)
A1	7,500	15	6.3	31.3	10.3	12.6
A2	3,344	10	6.2	22.3	6.7	9.1
A3	975	2.5	5.4	38.7	8.8	10.7
L1	5,875	3	6.8	22.0	—[2]	—[2]
L2	40	1	6.8	21.7	9.2	4.9

[1] Mean of three determinations at 2 to 3 cm below the soil surface.
[2] Data not available.

for approximately 12 wk before sampling, while *Lonicera* was sampled 16 wk after the transfer. Only leaves initiating and developing in the courtyard were used. The sampling and techniques for stomatal and trichome densities and for leaf thickness and area were those used on the July, 1978, field materials with the exception that *Arenaria* leaf surface area was not measured. The range of daily maximum temperature in the courtyard during most of the growth period was 18 to 37 C, while

with the findings of Buchauer (1971), who attributed the increase to the addition of large quantities of zinc oxide from smelter fumes to nearby soils. This amphoteric compound apparently acts as a base to neutralize the normally acidic soil. Presence of *Lonicera* at a site seemed to result in a higher pH, overriding possible location and texture effects, i.e., samples from similar areas adjacent to *Lonicera* sites had a lower pH.

The soil texture at all sites except L1

two
MPLE
areas
SO_2
pper
and
high
n the
These
metal
973)
soil
elters
grees

of all sample sites, although it did not have the lowest soil moisture. This is consistent with the lack of a vegetational windbreak on the open slope at that site.

STOMATAL AND TRICHOME DENSITIES. Those *Arenaria* populations exposed to the lowest pollution levels had the highest stomatal densities in both the 1977 and 1978 field determinations (Table 2). The greater density of A3 was especially evident on the upper surface, where all population means were significantly different at the 0.05 level during 1977. In 1978 a similar range of difference occurred among the populations, although fewer differences were statistically significant because of in-

A2	[illegible]	[illegible]	—	—
A3	137.2[a, A]	161.1[b, B]	—	165.7[a, B]

[1] Means in a vertical column followed by the same lower-case letter are not significantly different at the 0.05 level.
[2] Means in a horizontal row followed by the same upper-case letter are not significantly different at the 0.05 level.
[3] Data not available.

creased variance within populations. Trichome density showed the opposite trend—as pollution levels decreased, trichome densities decreased in all field comparisons (Table 3). All lower surface trichome density means during 1977 were significantly different, while only population A3, with its virtually glabrous upper leaf surfaces, was significantly different from other populations in upper surface means. The population values were more similar during 1978, while the upper surface densities were approximately double those of 1977.

Table 3. Upper and lower leaf surface trichome density for the three *Arenaria* populations growing under different conditions. Values are trichomes/mm² surface area.

Upper surface				
	Field			
Population	1977	1978	Greenhouse March, '78	Courtyard June, '78
A1	0.38[a1, A2]	0.67[a, B]	0.68[a, B]	0.59[a, B]
A2	0.33[a, A]	0.63[a, A]	—[3]	—
A3	0.02[b, A]	0.55[a, B]	1.14[a, C]	0.23[b, D]

Lower surface				
	Field			
Population	1977	1978	Greenhouse March, '78	Courtyard June, '78

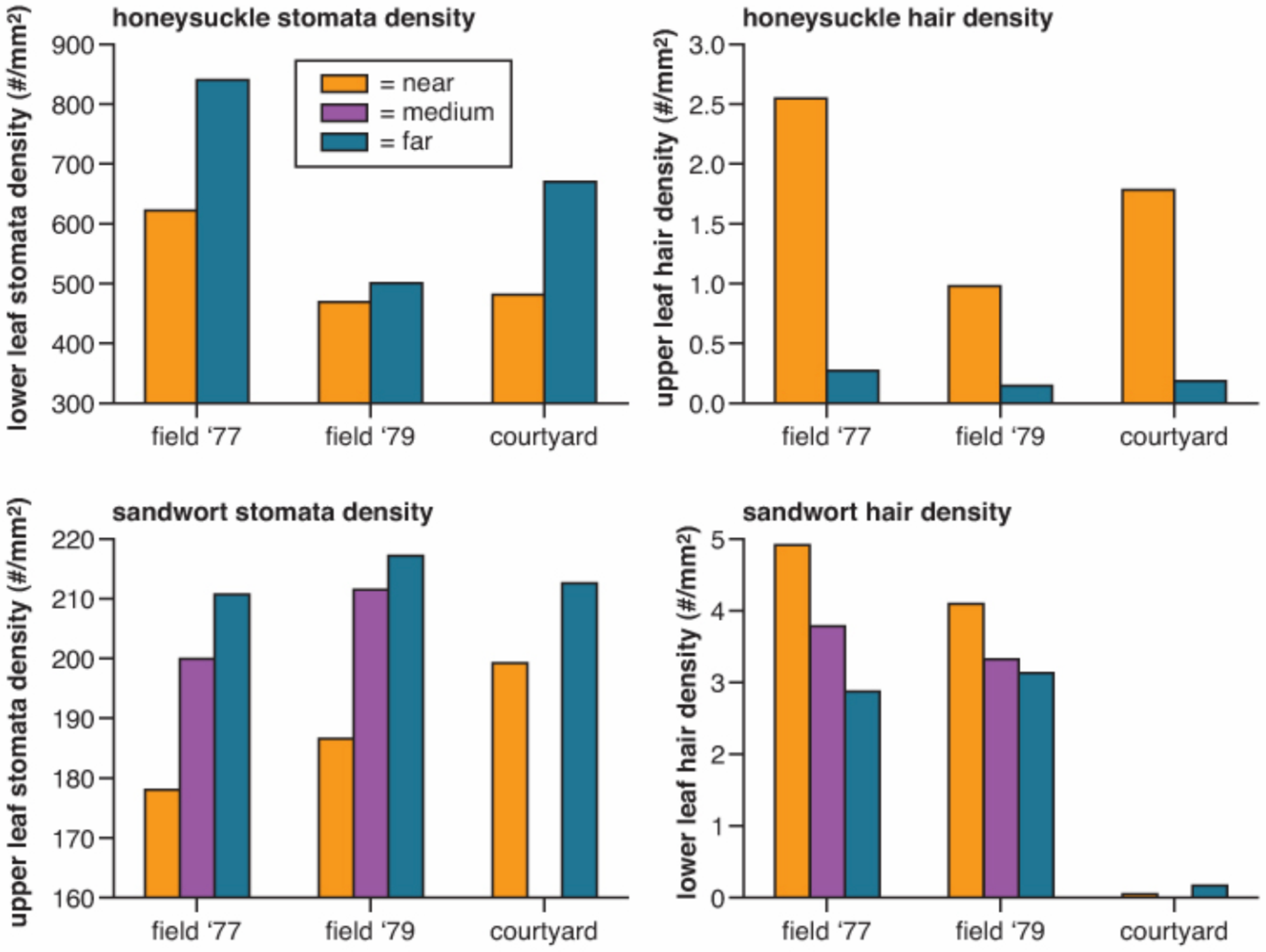


Figure 16.7 Stomata and hair densities of two plants collected at two times and grown in controlled conditions in a courtyard. Sandwort plants from the intermediate site were not grown in the courtyard. Data from Caiazza & Quinn, 1980, Tables 2 & 3.

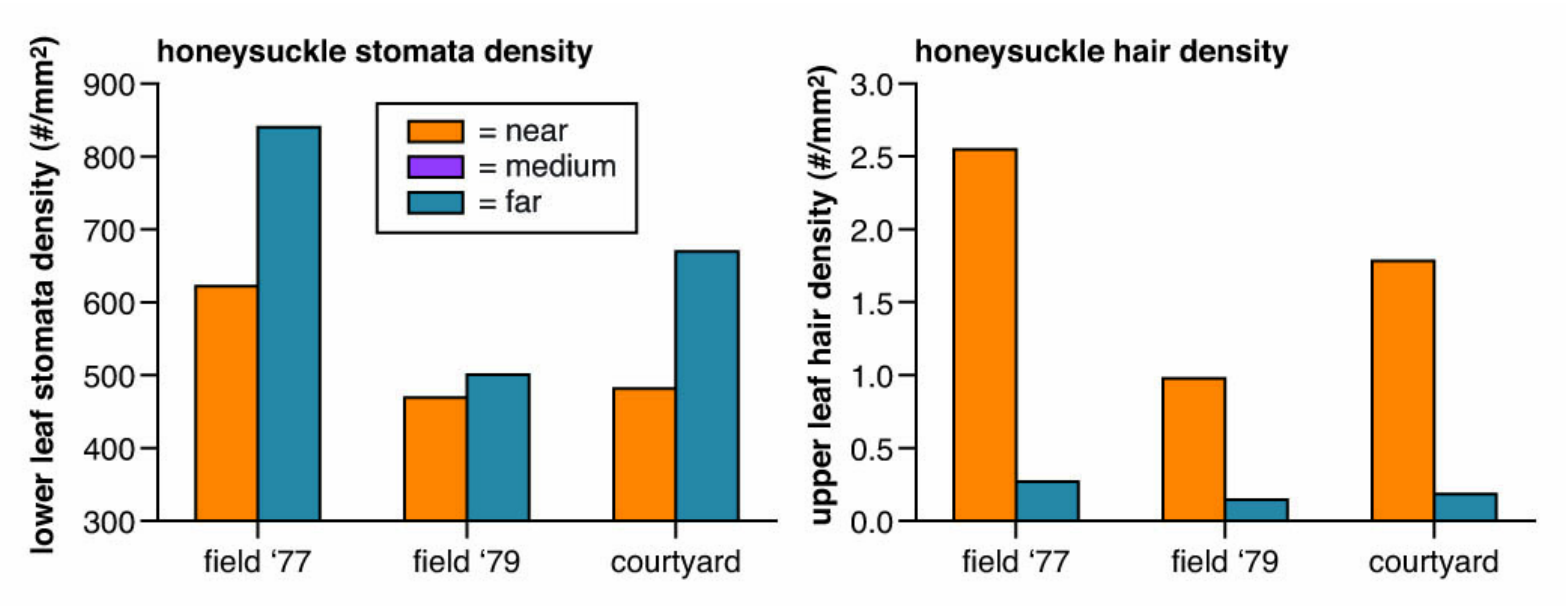


Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

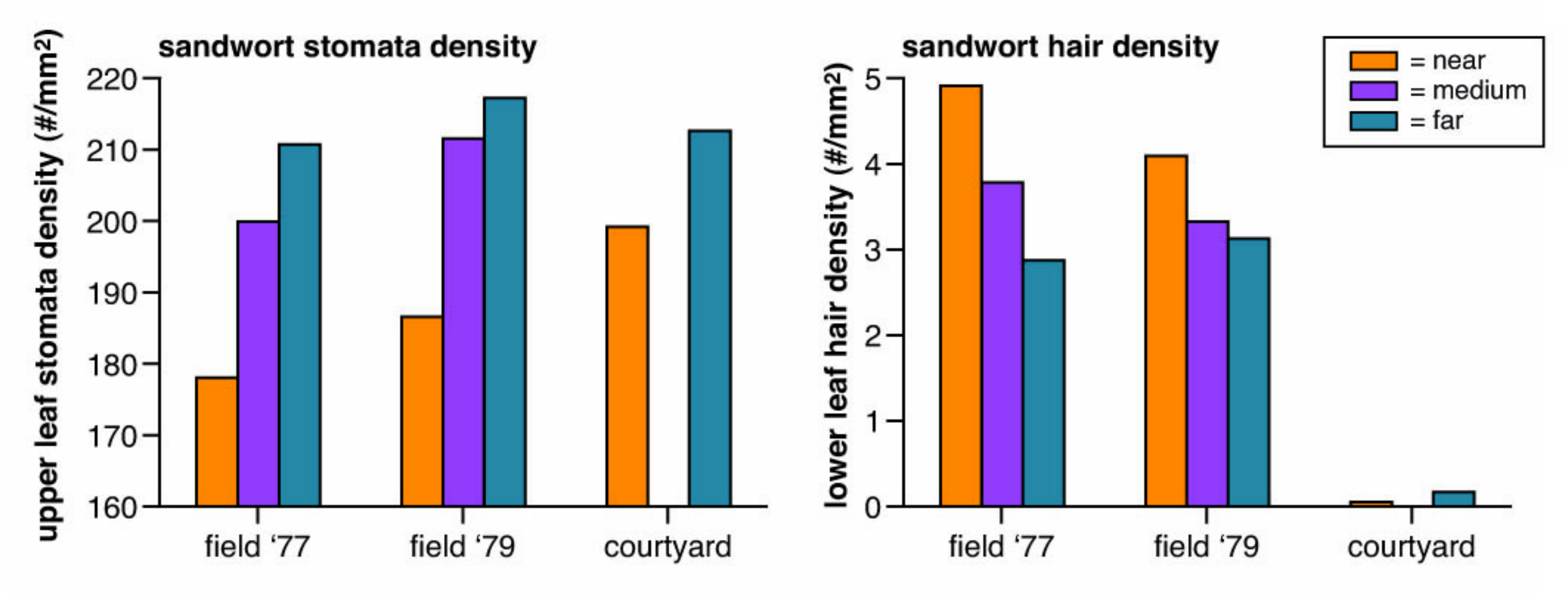
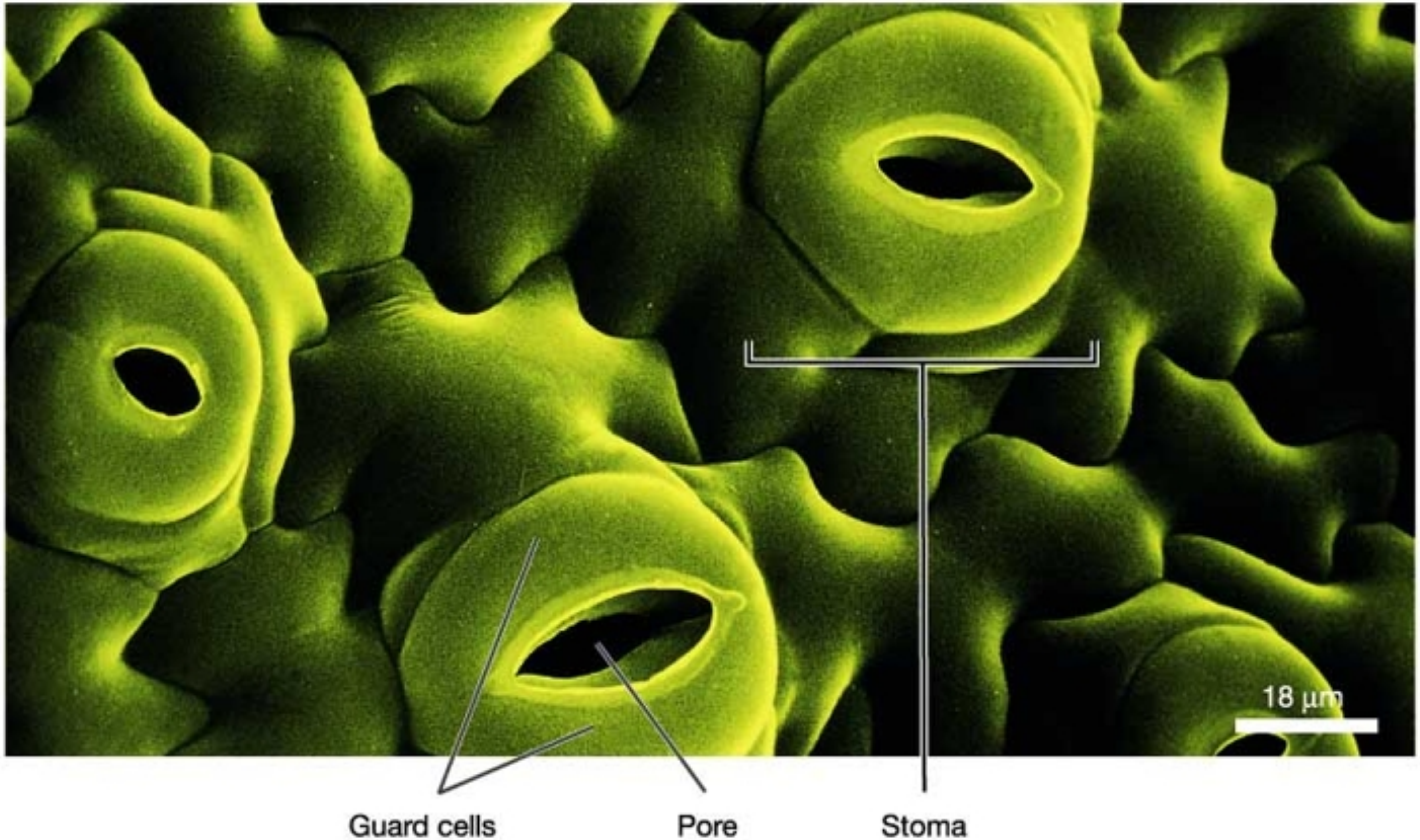
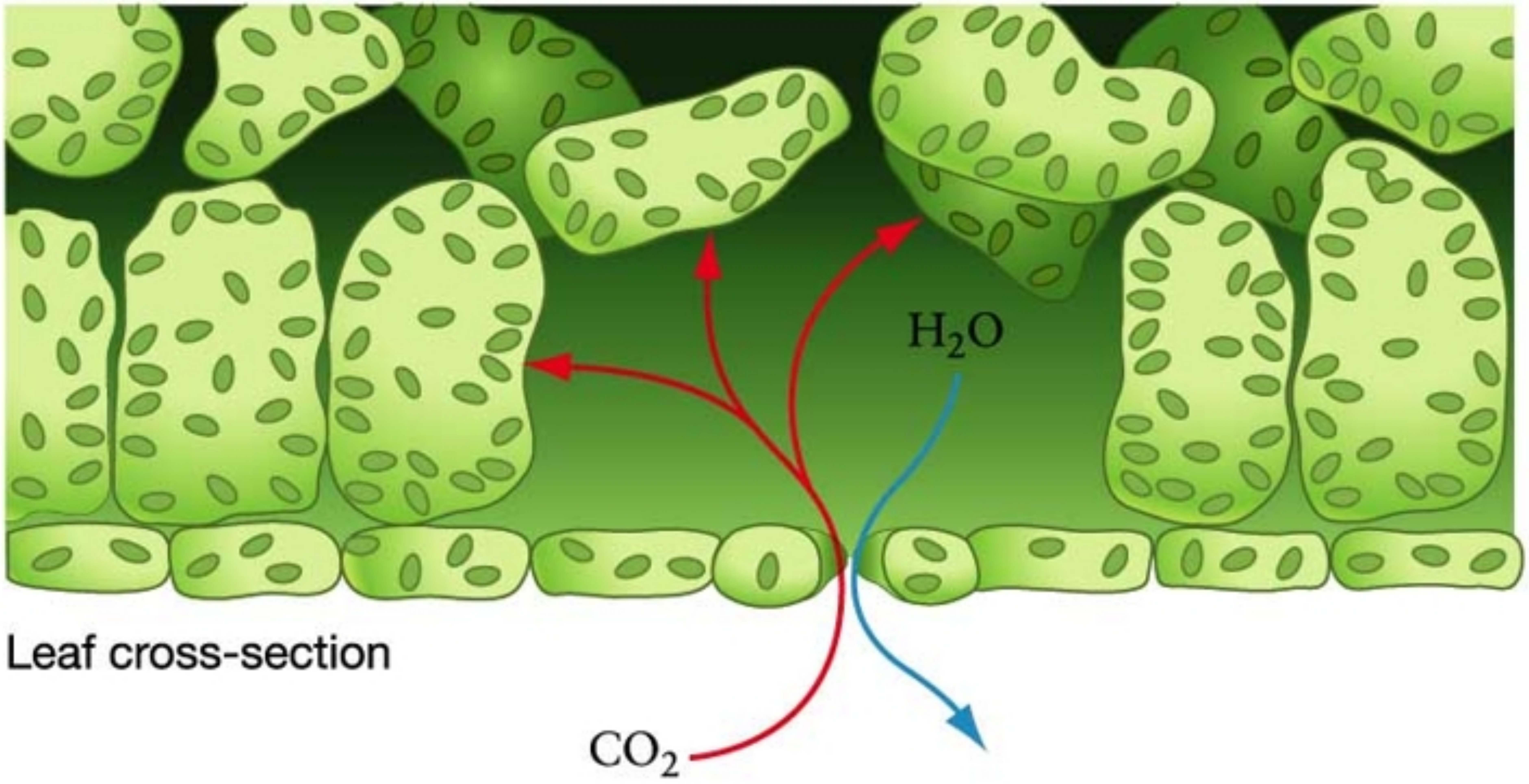


Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

Is it the metals in the soil?


18 µm
Guard cells
Pore
Stoma



H2O
Leaf cross-section
CO2

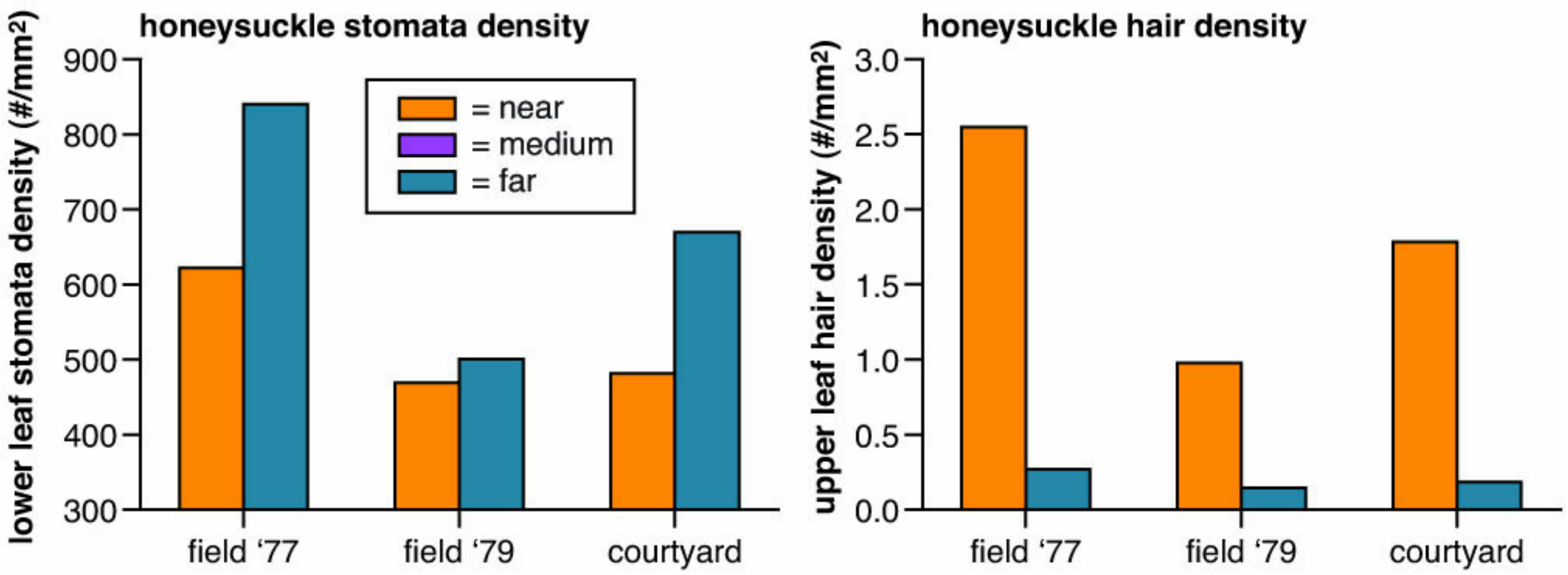
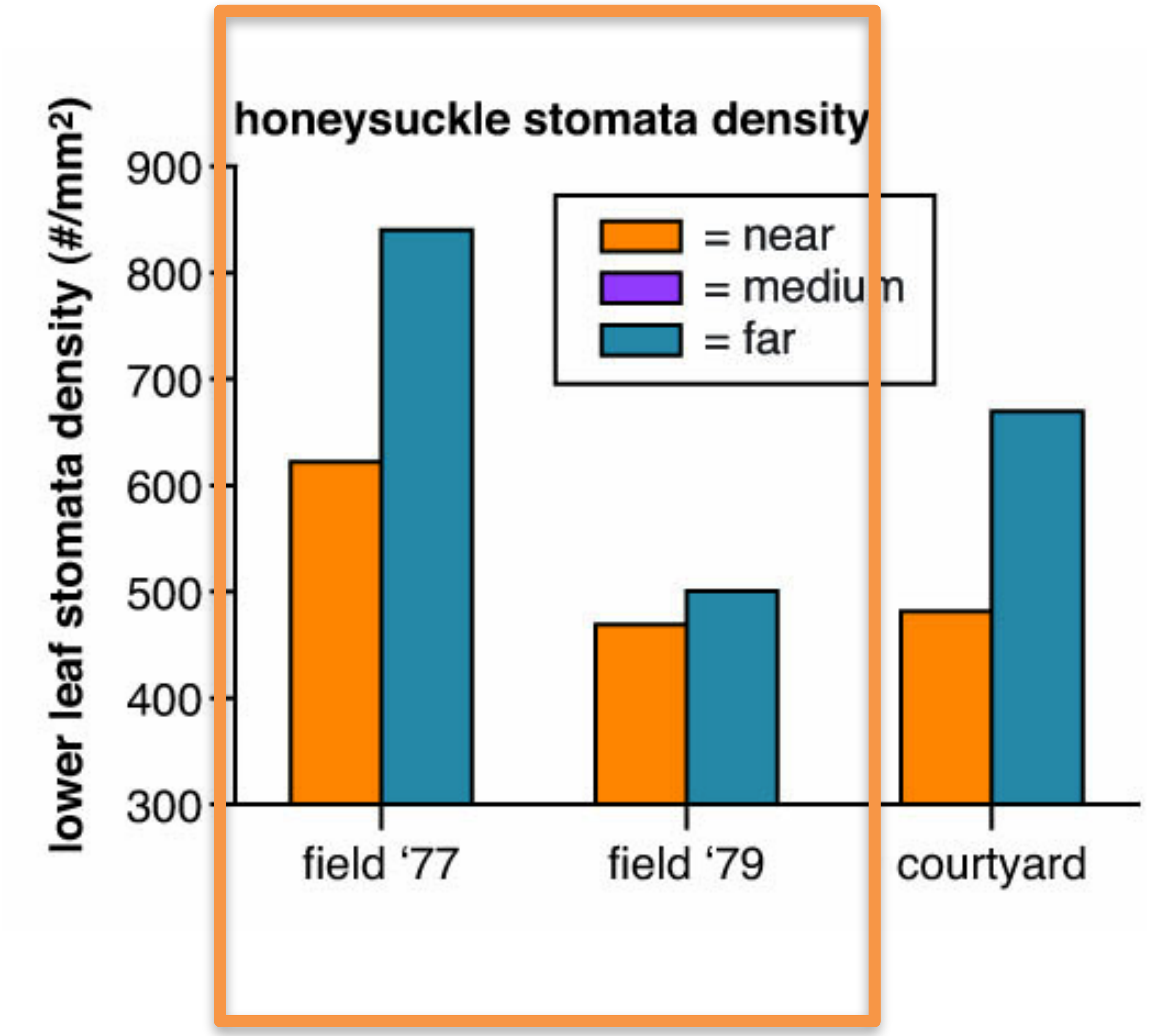


Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

Stomata and hair densities of honeysuckle collected at two times and grown in controlled conditions

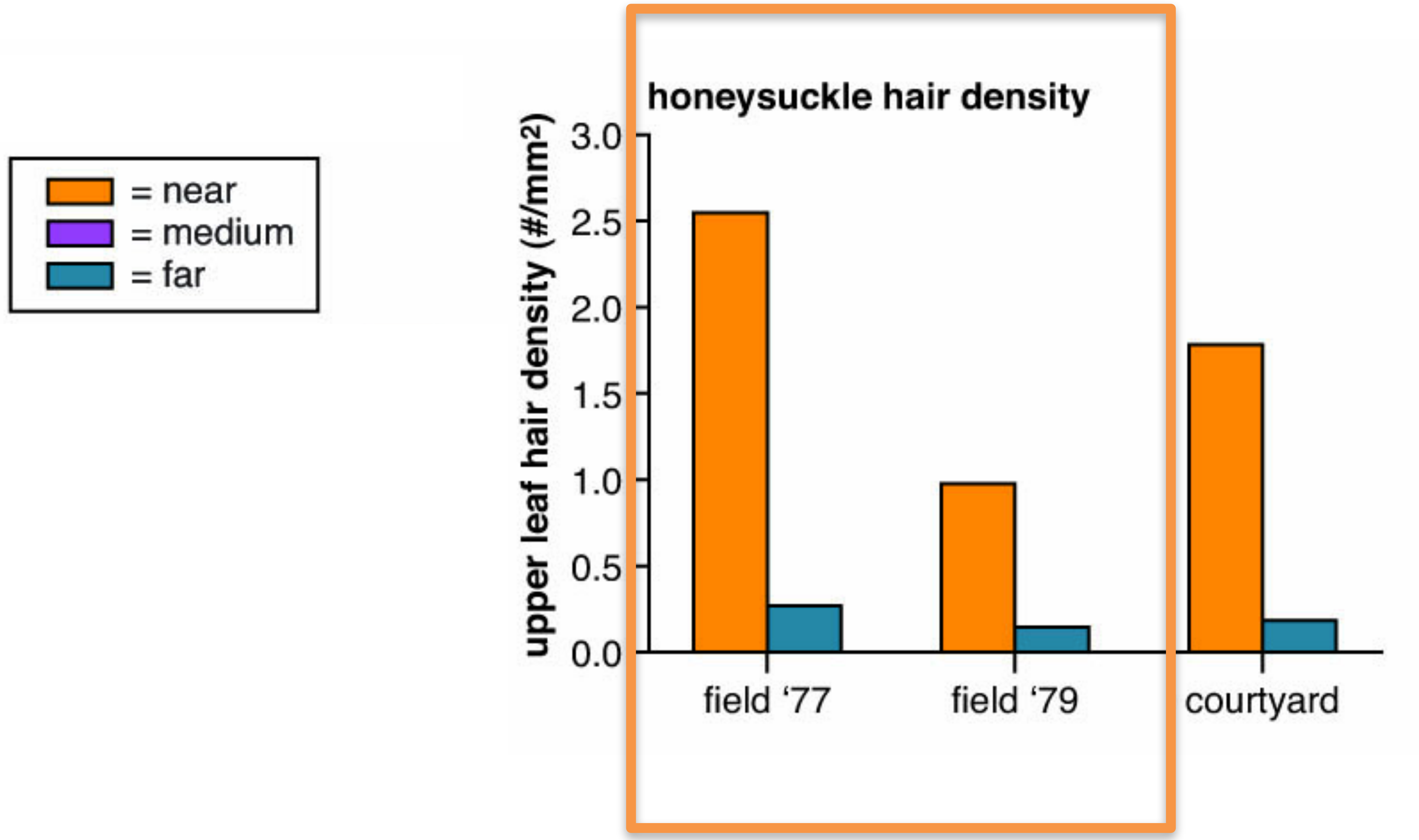


What is the effect of distance to smelter on stomata density?

Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

Stomata and hair densities of honeysuckle collected at two times and grown in controlled conditions



What is the effect of distance to smelter on hair density?

Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

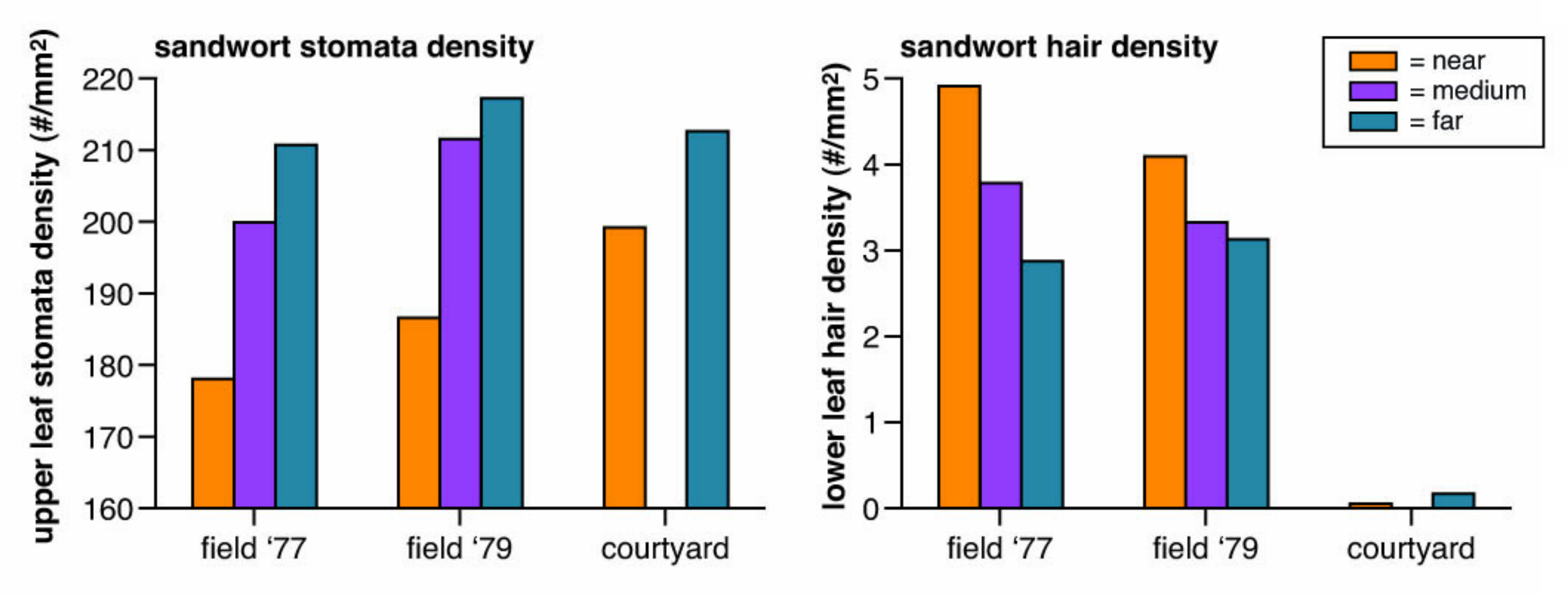
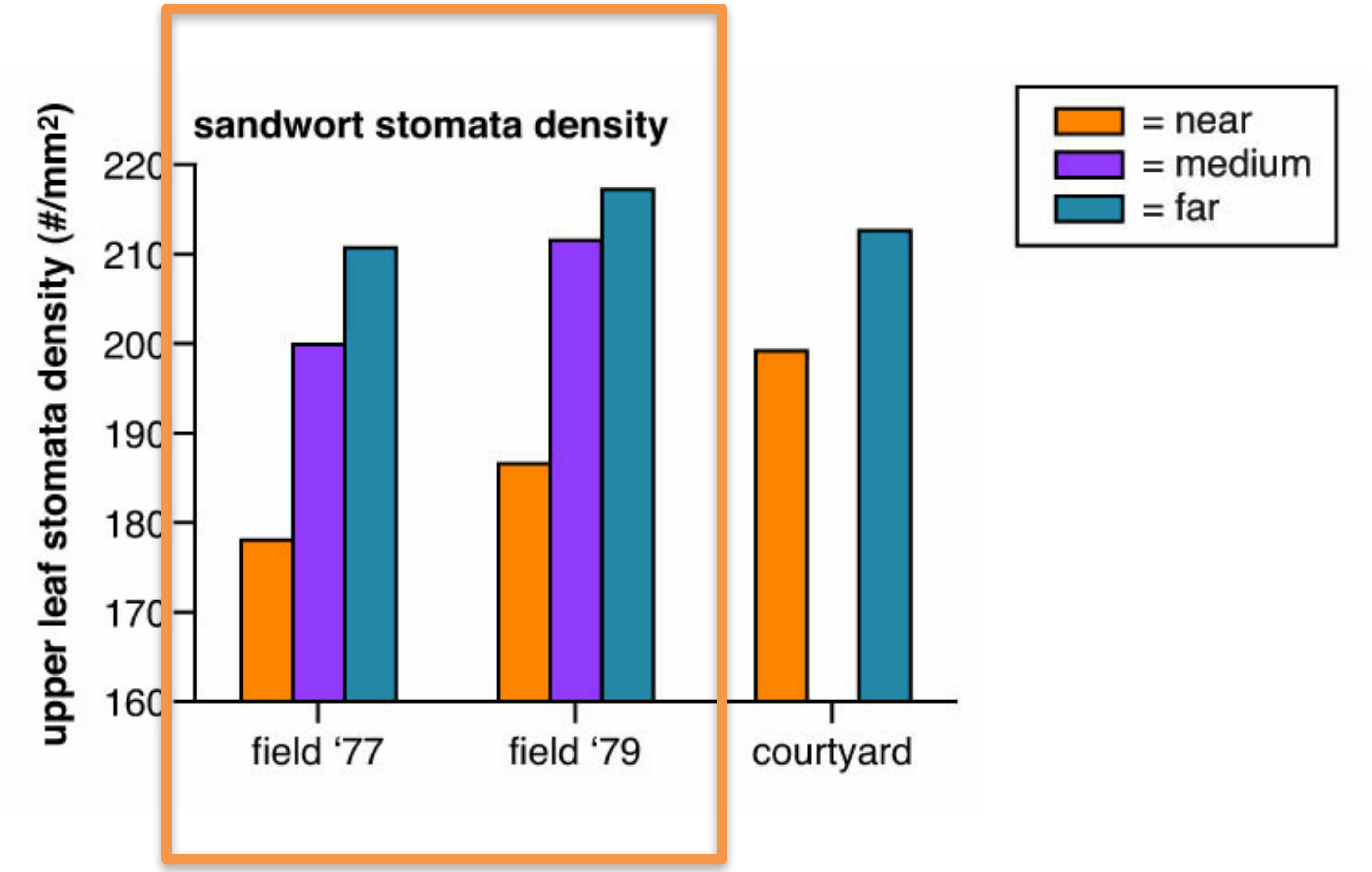


Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

Stomata and hair densities of sandwort collected at two times and grown in controlled conditions

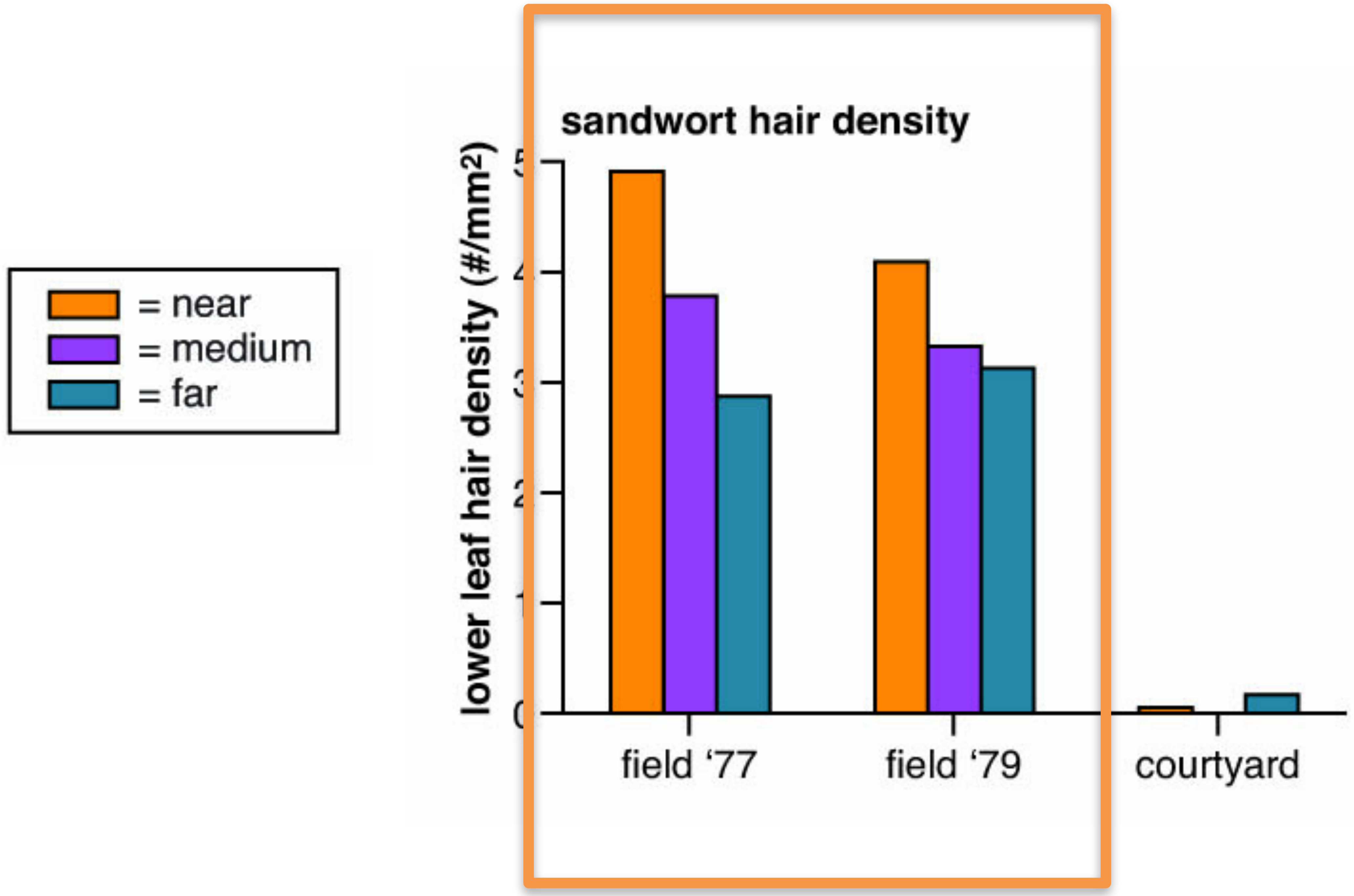


What is the effect of distance to smelter on stomata density?

Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

Stomata and hair densities of sandwort collected at two times and grown in controlled conditions

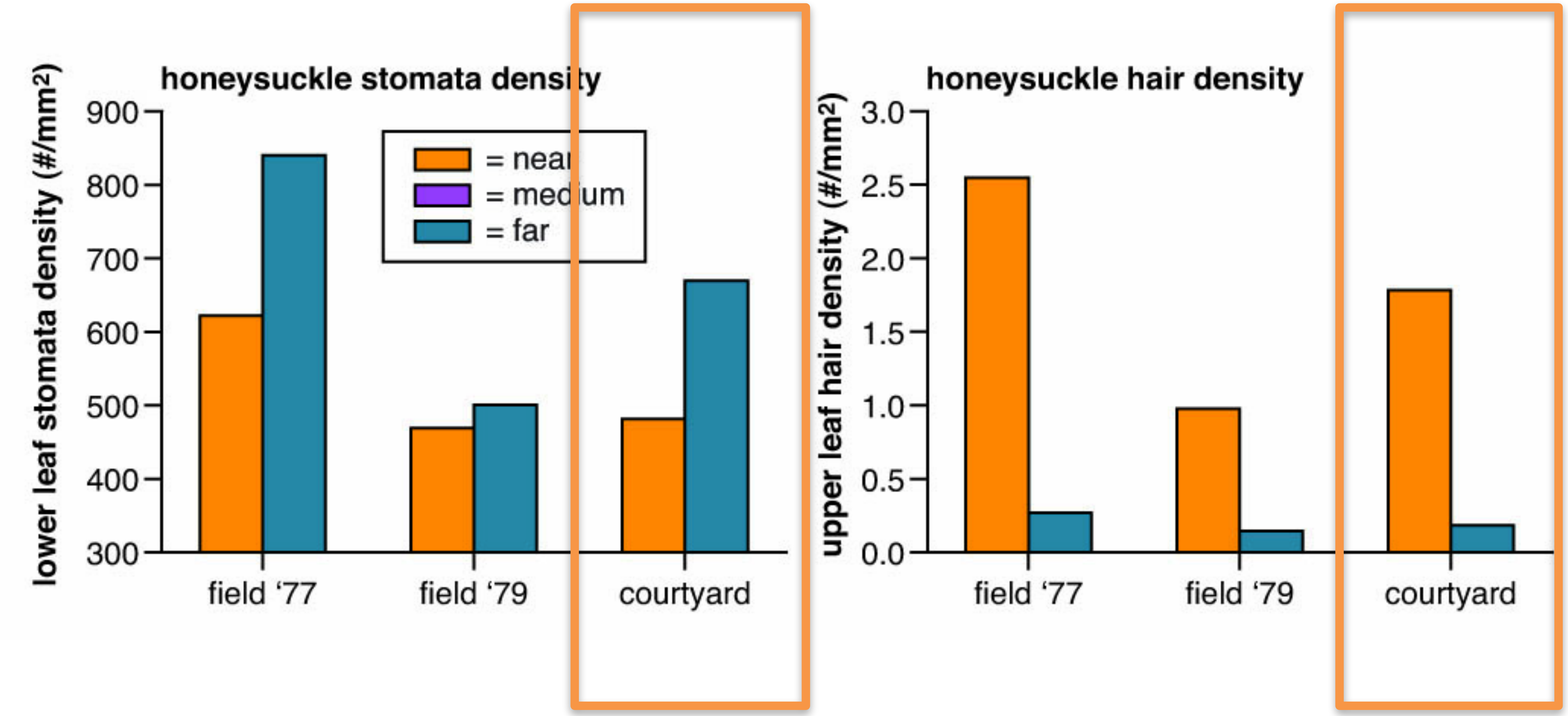


What is the effect of distance to smelter on hair density?

Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

Stomata and hair densities of honeysuckle collected at two times and grown in controlled conditions

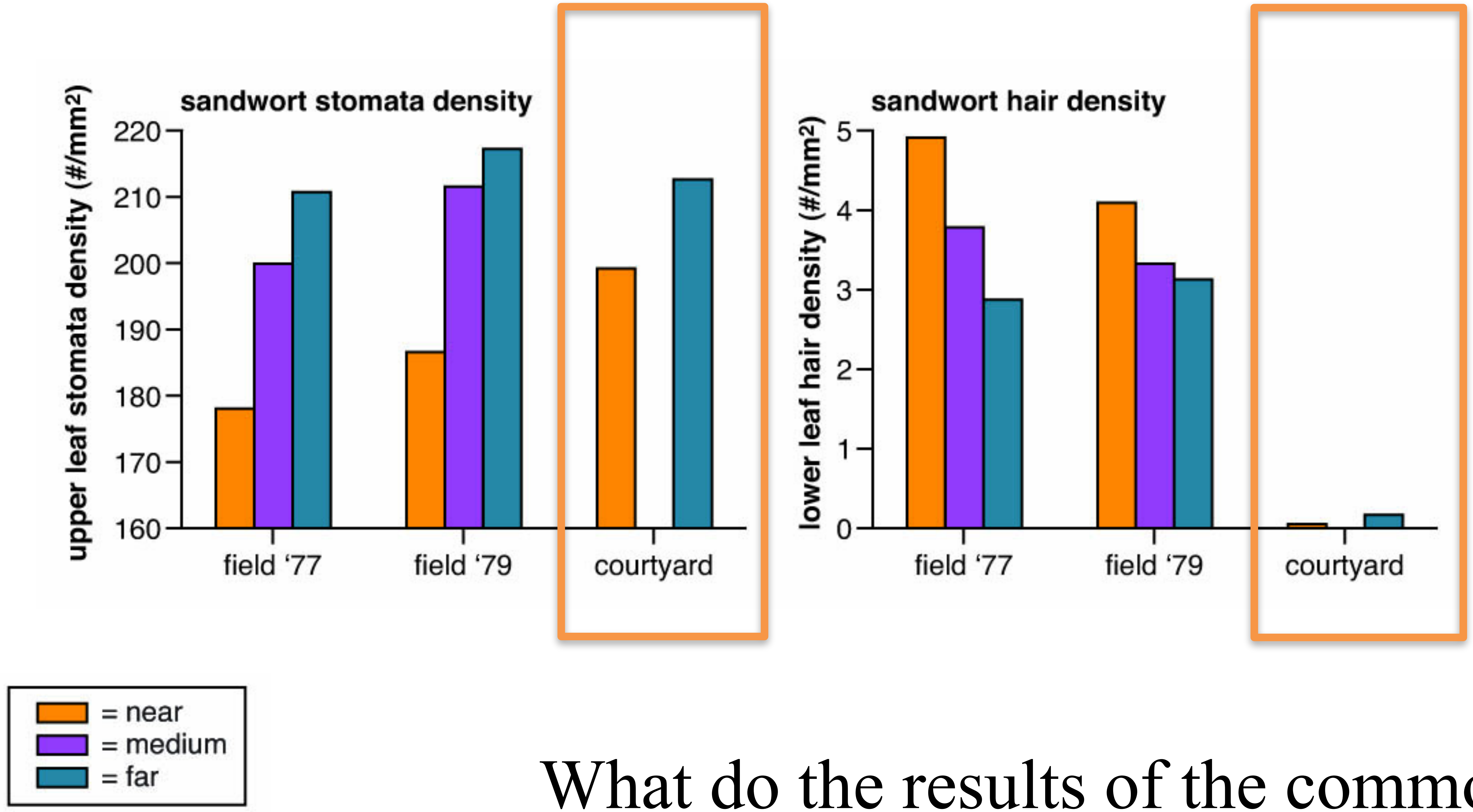


What do the results of the common garden experiment show?

Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

Stomata and hair densities of sandwort collected at two times and grown in controlled conditions



What do the results of the common garden experiment show?

Figure 16.7

Data from Caiazza & Quinn, 1980, Table 2 and 3.

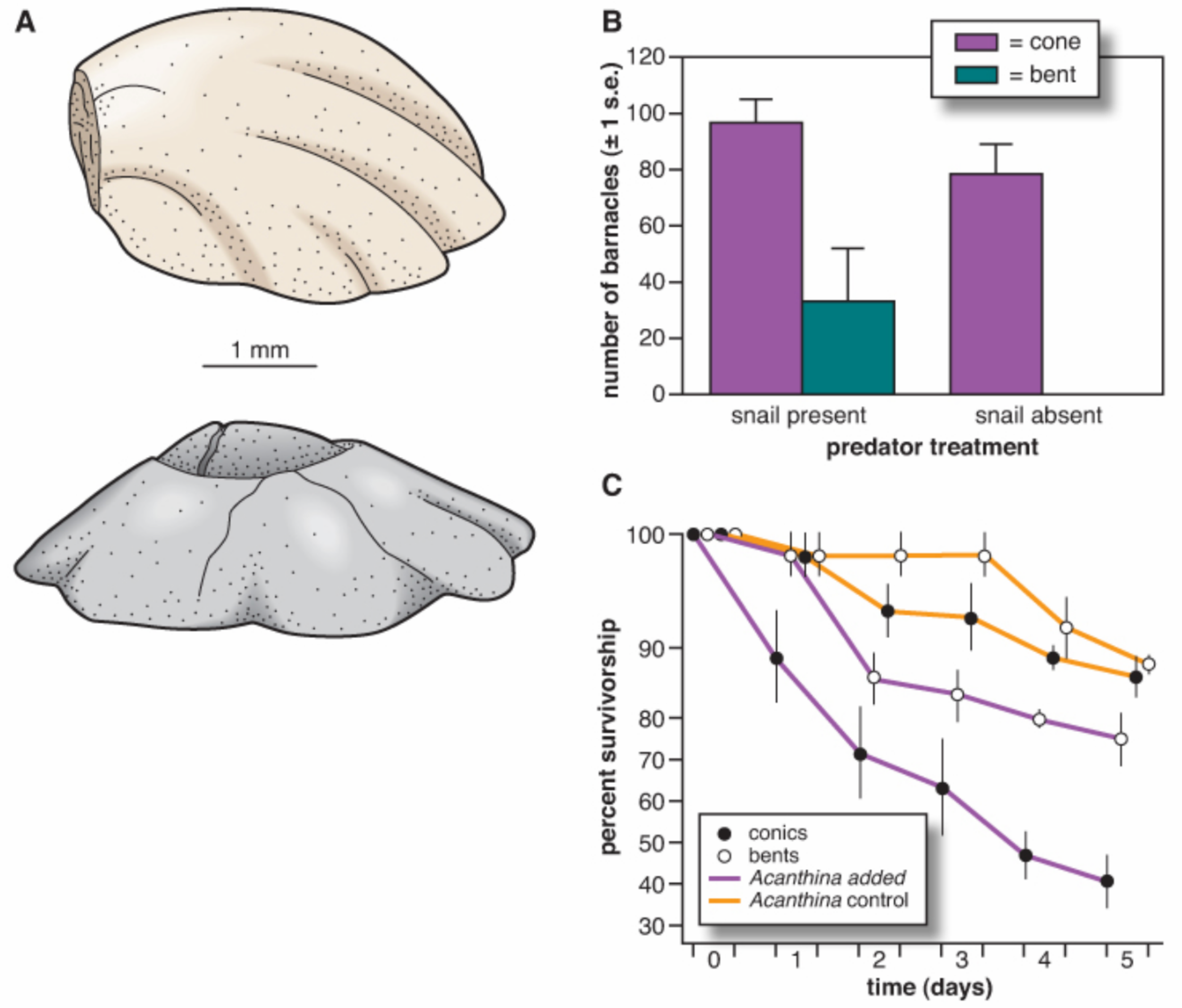


Figure 16.8 Responses of the acorn barnacle (*Chthamalus anisopoma*) to the snail predator (*Acanthina*). **A,** Bent (top) and cone (bottom) shell shapes. **B,** Results of predator exclusion experiment. **C,** Survival of two types of barnacles in plots with and without the predator. From Lively, 1986, Figure 1 **(A)**; Table 1 **(B)**; Figure 3 **(C)**.

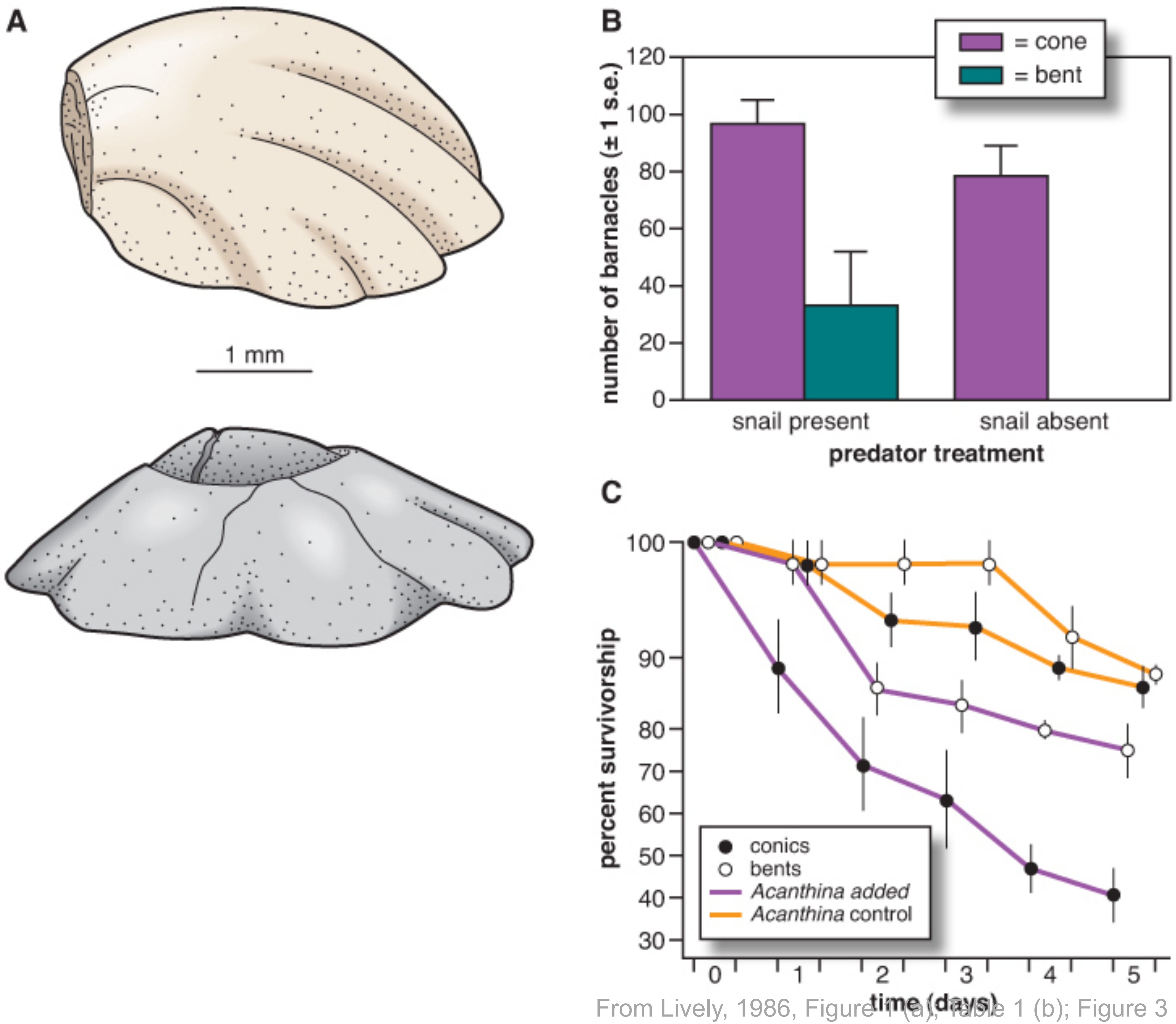

A
1 mm
B
= cone
= bent
number of barnacles (± 1 s.e.)
120
100
80
60
40
20
0
snail present
snail absent
predator treatment
C
percent survivorship
100
90
80
70
60
50
40
30
conics
bents
Acanthina added
Acanthina control
0
1
2
3
4
5
time (days)

Figure 16.8

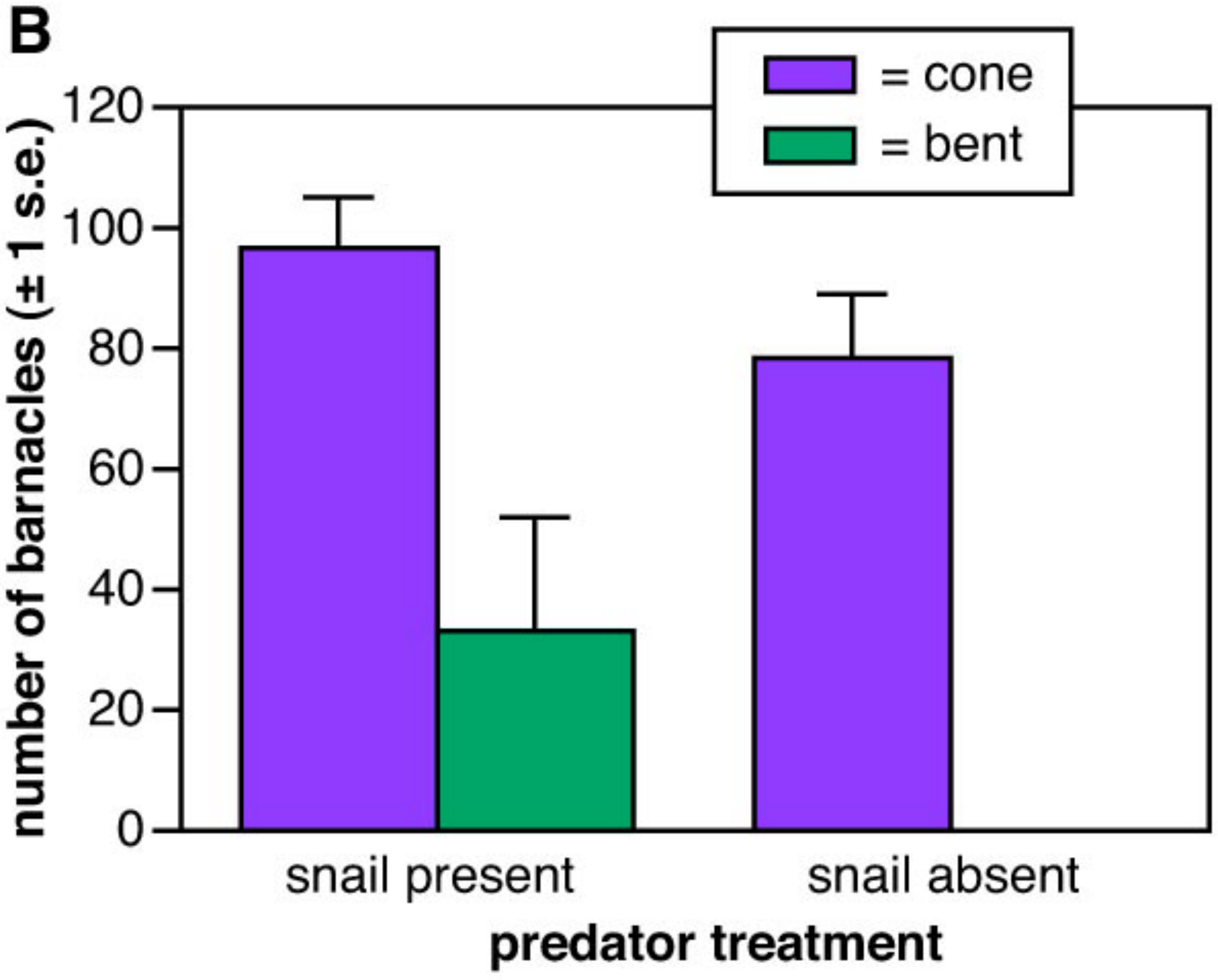
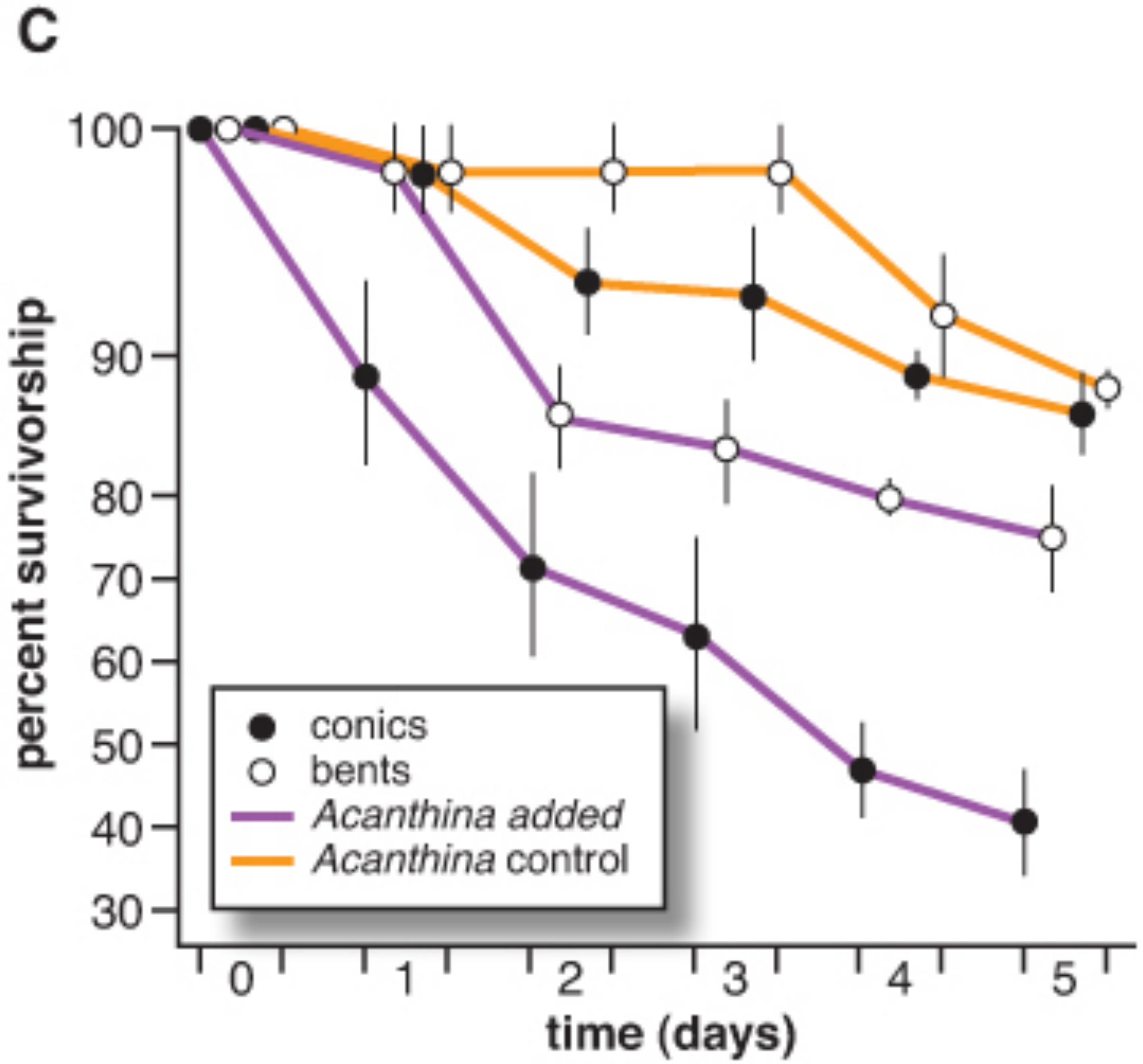

B
= cone
= bent
number of barnacles (± 1 s.e.)
120
100
80
60
40
20
0
snail present
snail absent
predator treatment

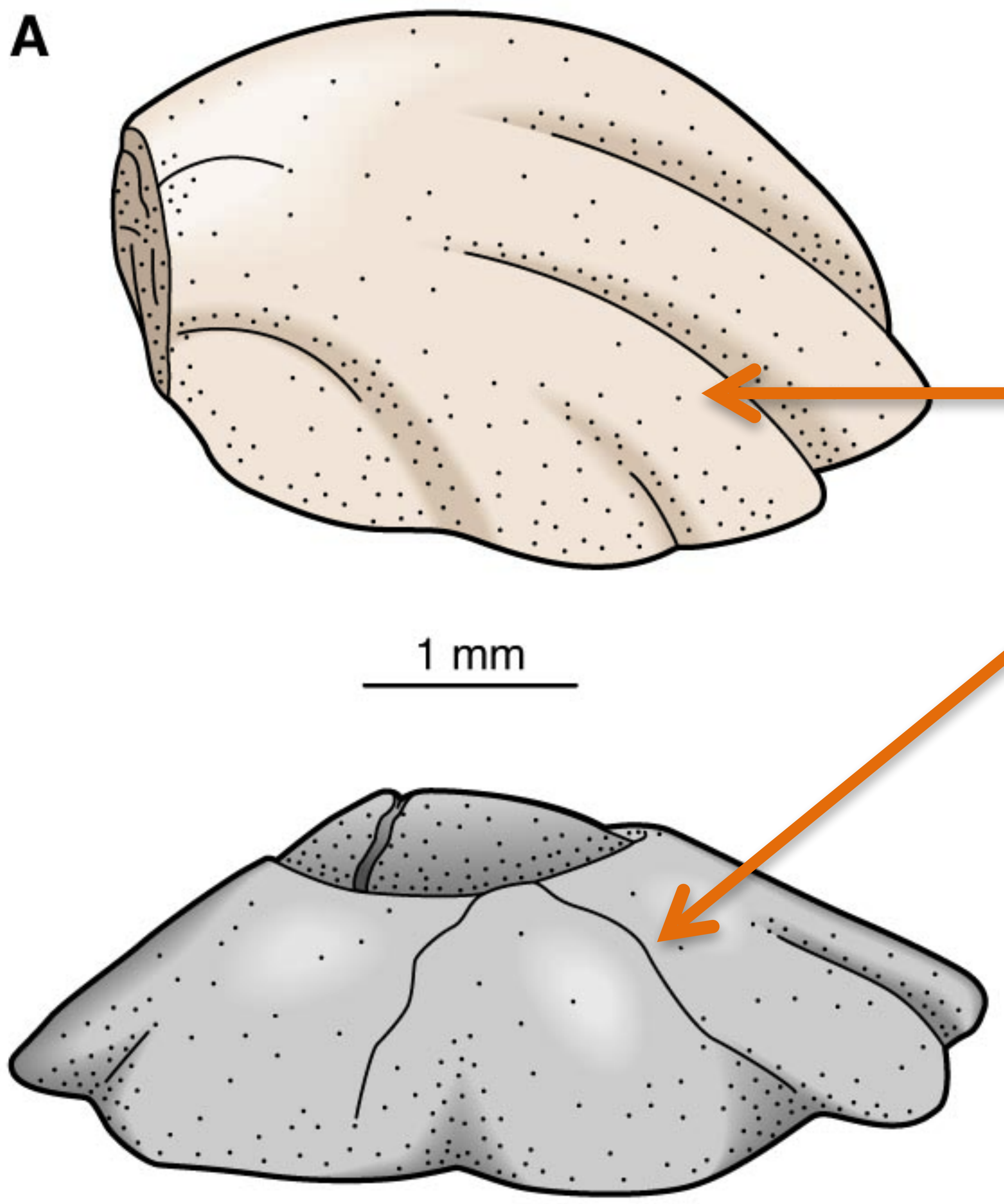
Figure 16.8



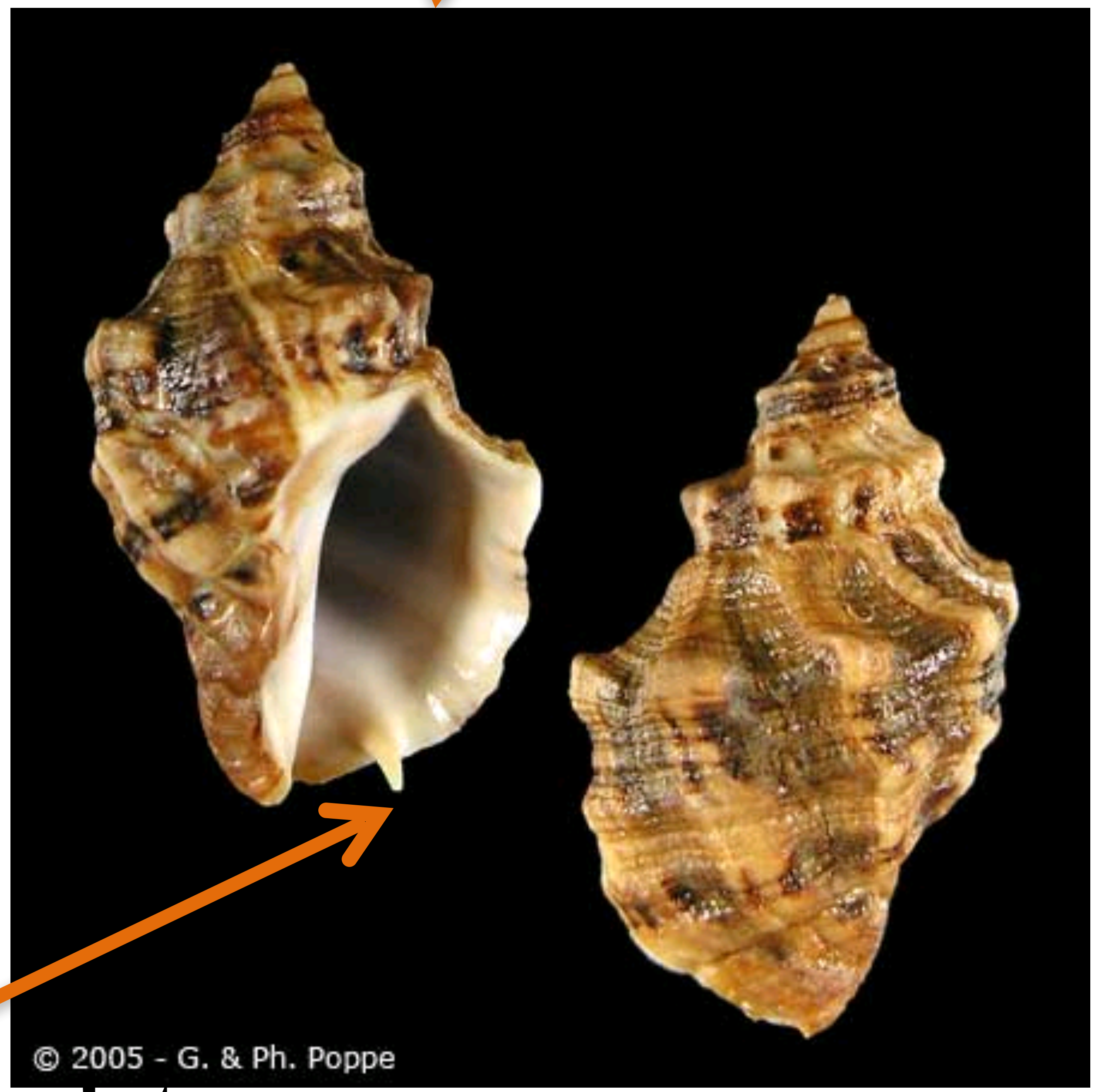
c
percent survivorship
100
90
80
70
60
50
40
30
0
1
2
3
4
5
time (days)
conics
bents
Acanthina added
Acanthina control

Figure 16.8

Responses of the acorn barnacle (*Chthamalus anisopoma*) to the snail predator (*Acanthina*).



bent and cone shell shapes



Spine used to pry barnacles

Figure 16.8

Responses of the acorn barnacle (*Chthamalus anisopoma*) to the snail predator (*Acanthina*).

results of predator exclusion experiment

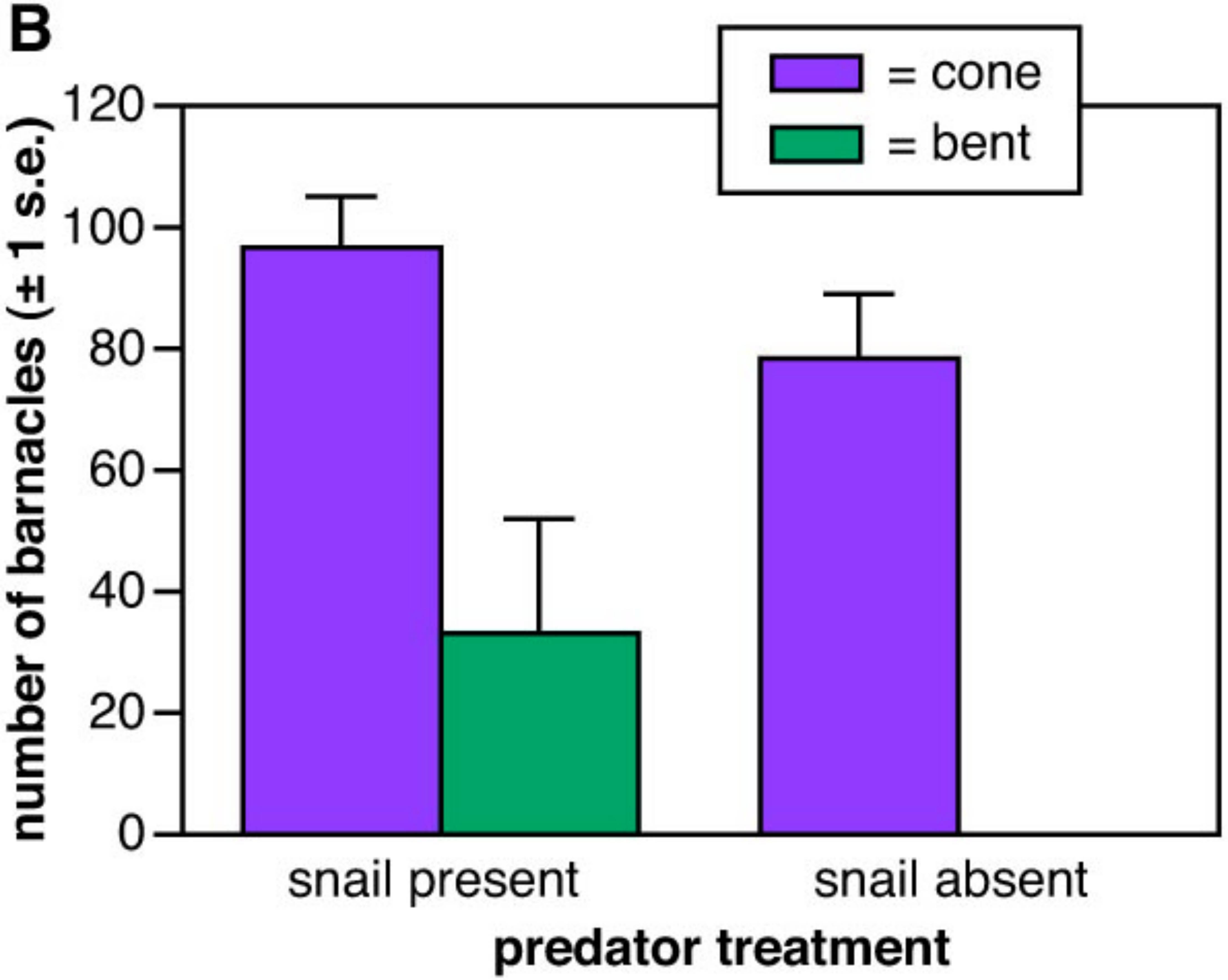


Figure 16.8

Responses of the acorn barnacle (*Chthamalus anisopoma*) to the snail predator (*Acanthina*).

results of predator exclusion experiment

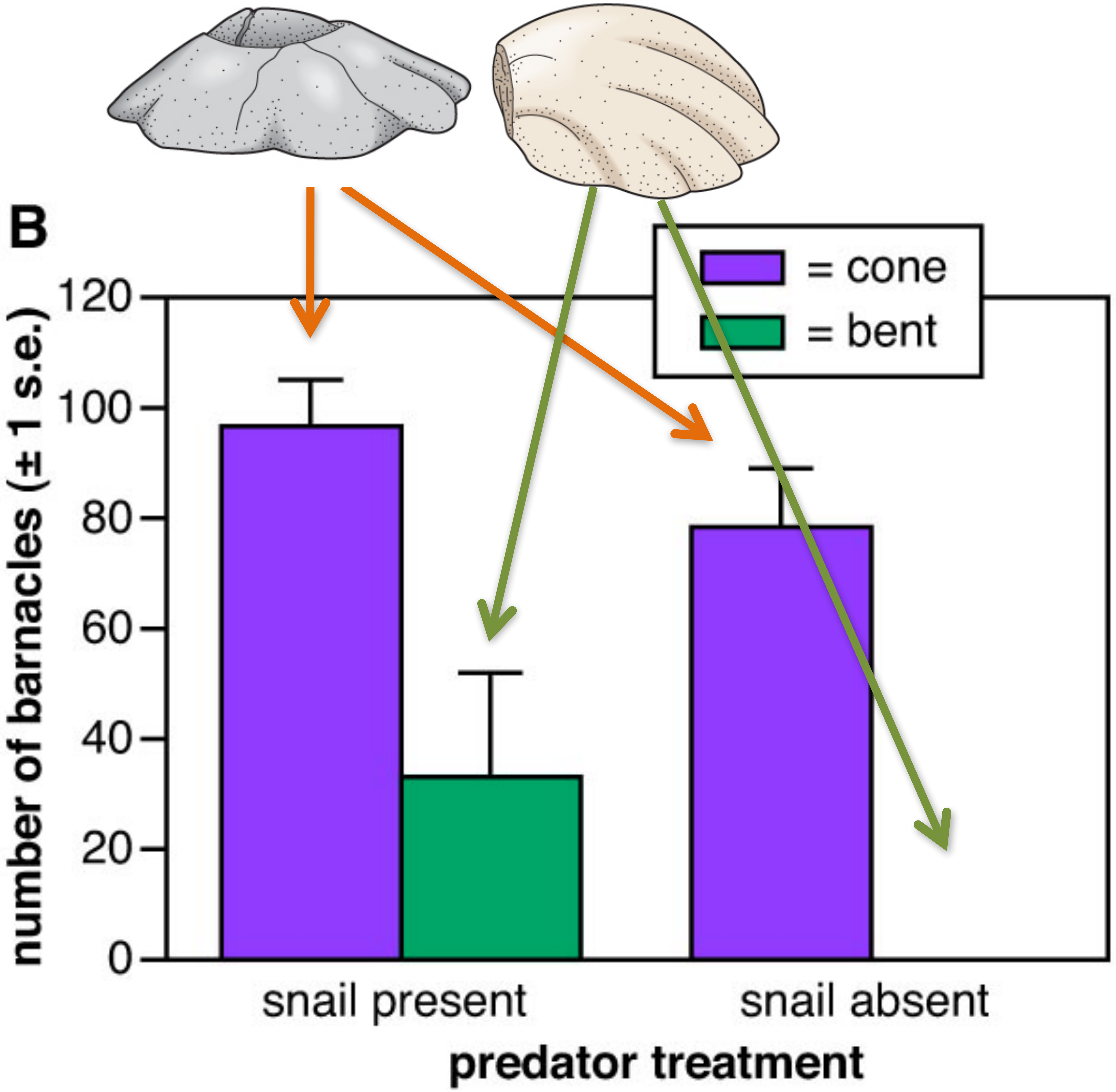


Figure 16.8

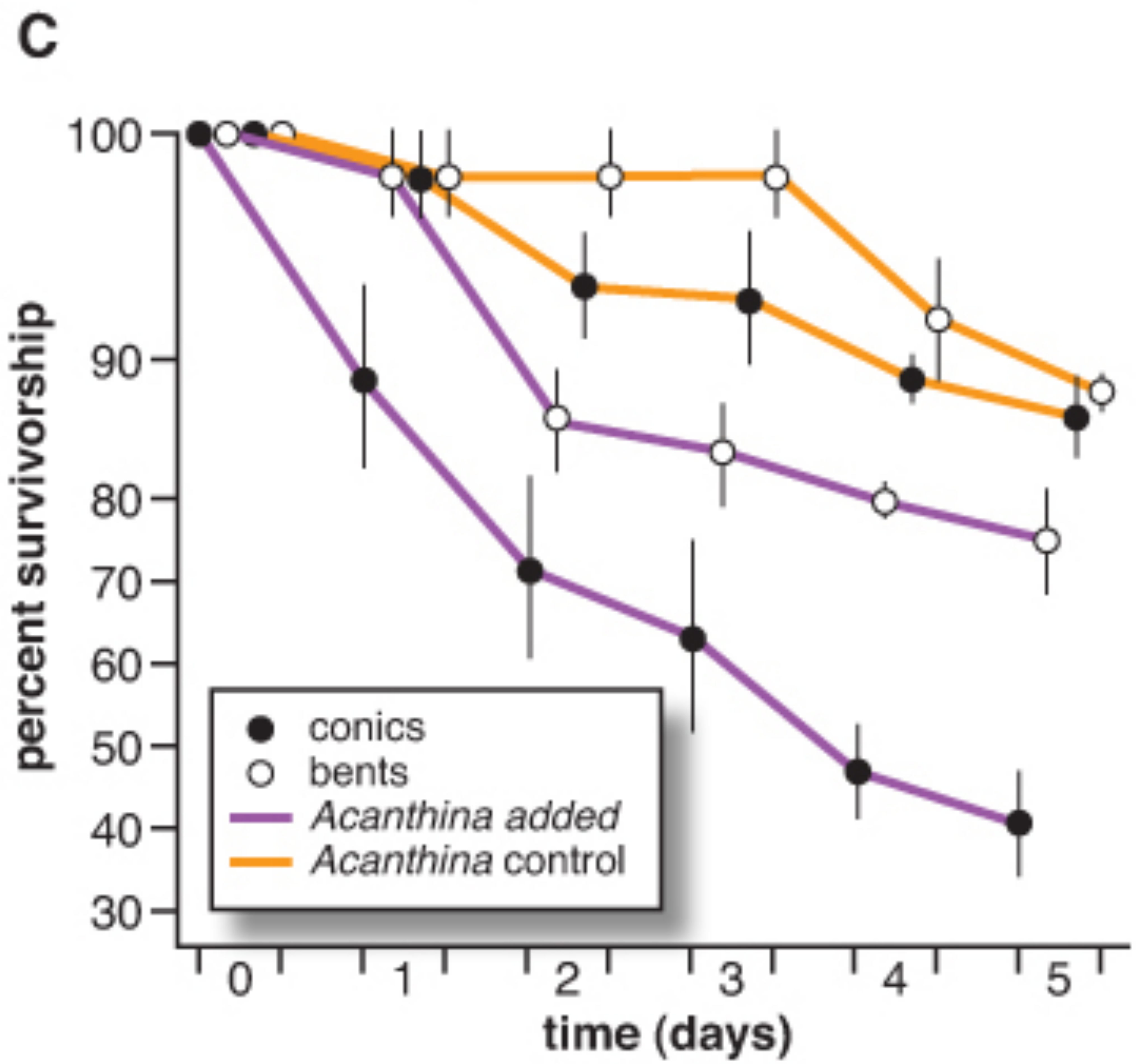

c
100
90
80
70
60
50
40
30
percent survivorship
0
1
2
3
4
5
time (days)
conics
bents
Acanthina added
Acanthina control

Figure 16.8

Responses of the acorn barnacle (*Chthamalus anisopoma*) to the snail predator (*Acanthina*).

Survival of barnacles

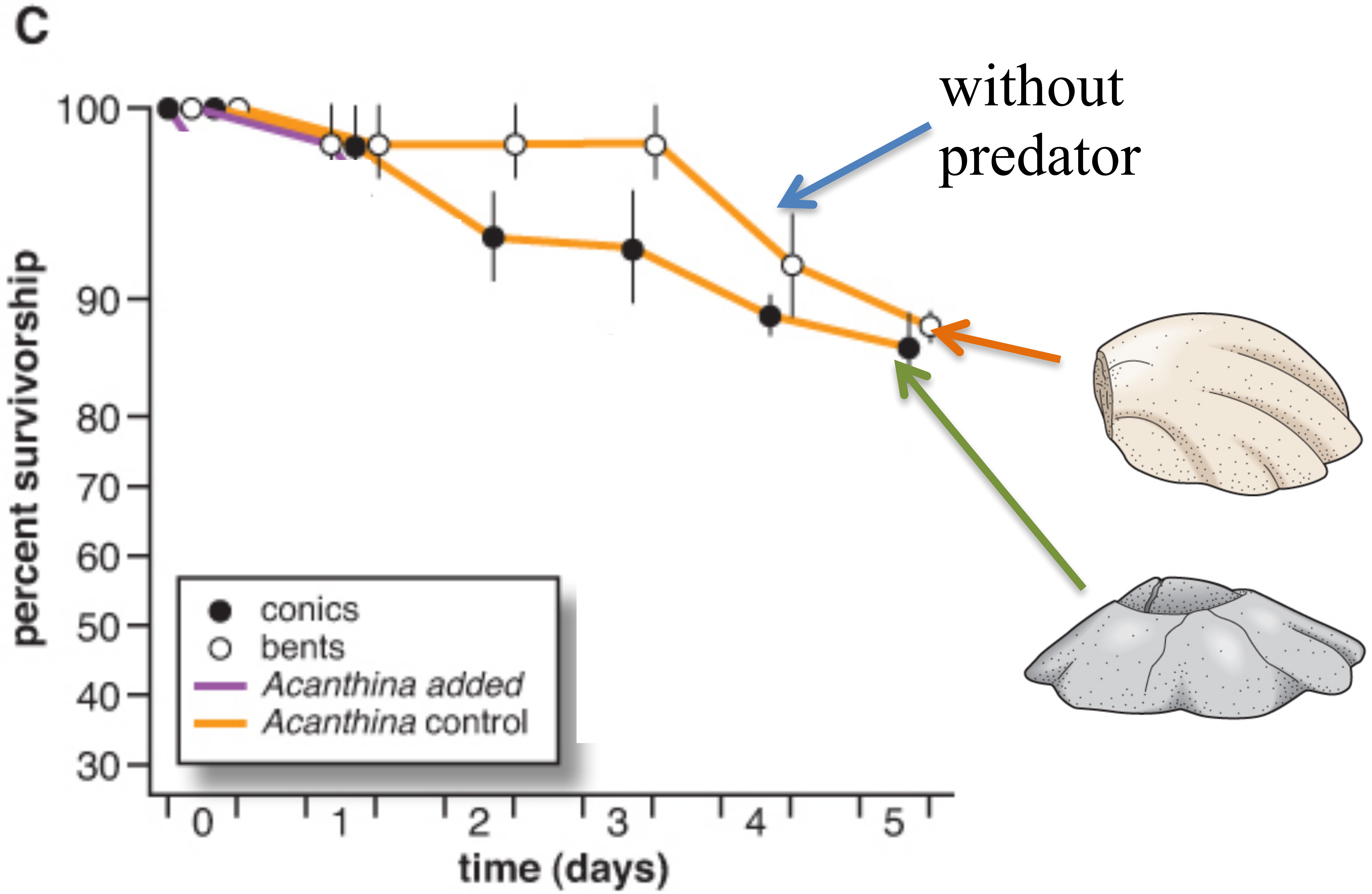


Figure 16.8

Responses of the acorn barnacle (*Chthamalus anisopoma*) to the snail predator (*Acanthina*).

Survival of barnacles

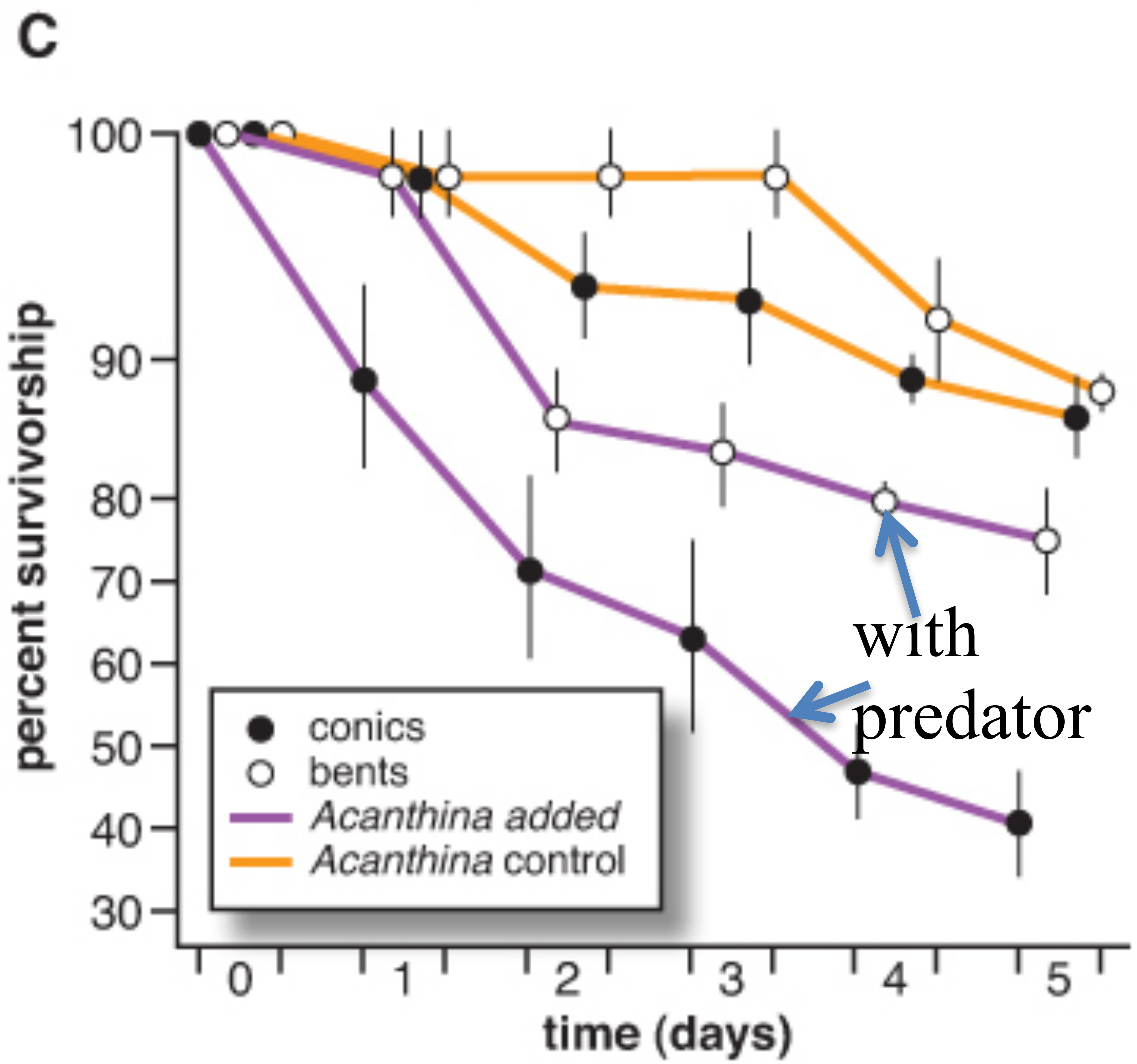


Figure 16.8

Responses of the acorn barnacle (*Chthamalus anisopoma*) to the snail predator (*Acanthina*).

Survival of barnacles

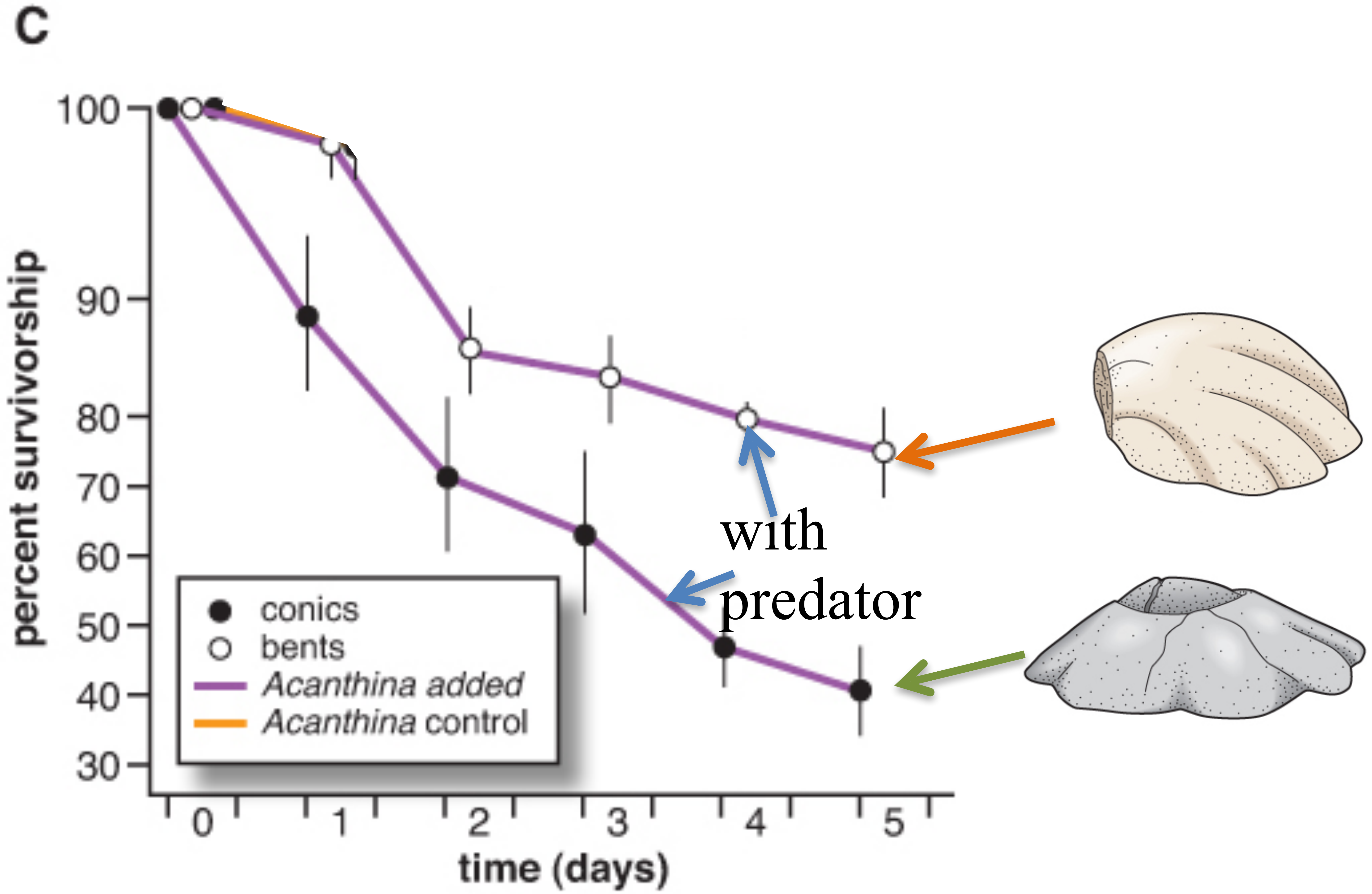


Figure 16.8

Curious about real methods used?

Evolution, 40(2), 1986, pp. 232–242

PREDATOR-INDUCED SHELL DIMORPHISM IN THE ACORN BARNACLE *CHTHAMALUS ANISOPOMA*

CURTIS M. LIVELY[1]
Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, AZ 85721

Abstract.—Field experiments were conducted in order to determine the nature of shell dimorphism in the acorn barnacle *Chthamalus anisopoma* and the adaptive significance of the atypical form. The typical morph has the conical shape which is characteristic of acorn barnacles, while the atypical morph appears bent over, with the rim of its aperture oriented perpendicular to its base. The experiments showed that: 1) the bent-over morphology is an environmentally-induced developmental response to the presence of a carnivorous gastropod (*Acanthina angelica*) and 2) that "bents" are more resistant than "conics" to specialized predation by this snail. The results also showed that predation by *A. angelica* is patchy and heaviest in the near vicinity of cracks and crevices, which it uses as refuges during periods of tidal inundation. Because predation is patchy and bents are less fecund and grow slower than conics, the conditional developmental strategy is likely to be favored over strict genetical control of shell morphology.

Received December 7, 1984. Accepted August 16, 1985

Discontinuous variation within populations suggests natural selection against genotypes which produce intermediate phenotypes (Mather, 1955) as well as trade-offs in fitness among the different morphs due to a variable environment (Levins, 1962, 1968). This is true whether the phenotypes are fixed at syngamy (i.e., genetically determined) or result from genetically based switches in development in response to specific environmental cues (i.e., Mayr's [1963]

rocky intertidal shores in the northern Gulf of California (Lively, 1984). The typical morph (called "conic") occurs throughout the Gulf (Newman and Ross, 1976) and has the conical, volcano-shaped shell which is characteristic of acorn barnacles (Darwin, 1854). The atypical morph (called "bent") is restricted to the northern Gulf and has the rim of its aperture in a plane which is perpendicular (rather than parallel) to its base (Fig. 1). A bivariate plot of the lengths

TABLE 1. The means (±standard errors) for the numbers of bent and conic morphs of *Chthamalus anisopoma* observed in the *A. angelica*/*N. funiculata* addition experiment.

Number of *A. angelica* added		Number of *N. funiculata* added				
		0	2	9	32	Row $\bar{x}$
0	conics	78.5 (±10.5)	182.0 (±12.0)	142.0 (±17.0)	132.0 (±45.0)	133.6 (±16.9)
	bents	0 (–)	0 (–)	0 (–)	0 (–)	0 (–)
5	conics	96.5 (±8.5)	69.0 (±8.0)	85.0 (±19.0)	79.5 (±53.5)	82.5 (±23.2)
	bents	33.0 (±19.0)	25.5 (±13.5)	25.5 (±14.5)	27.5 (±11.5)	27.9 (±5.7)

which the rock substratum was unbroken by cracks and crevices of the type normally suitable as refuges for *A. angelica*.

At each of the eight sites, four quadrats (15 × 15 cm) were established: two "near" (<20 cm) and two "far" (>40 cm) from crevices. All 32 quadrats were cleared of organisms by scraping and then "sterilized"

month for the first 14 months and then at 6–10 week intervals thereafter for an additional three years. On each sampling date, the number of *A. angelica* foraging both <20 cm and >20 cm from crevices was also recorded for each of the eight sites, the areas of which were later determined.